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WYE COLLEGE

Department of Hop Research

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1959

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INTRODUCTION

THIS twelfth annual report of the Department of Hop Research gives an encouraging account of continued progress in the study of the problems of the crop, the cultivation of which is a traditional part of the environment of Wye College. New techniques and concepts have enabled research to expand throughout the year; this increased activity results inevitably in pressure for a widening range of field trials to confirm the findings of laboratory and glasshouse work. An essential preoccupation of those in charge of hop research at Wye is to ensure flexibility in programme planning by maintaining in the College hop gardens a strategic reserve of space which is uncommitted to long-term experiments.

Signs of these healthy developments were apparent at the successful conference held at Wye in the Withersdane Hall in January, 1960, when the College was privileged to entertain a total of 250 hop growers and other guests. Current trends in hop research were examined in six papers presented on this occasion and the liveliness of the ensuing discussions gave evidence of that outside interest in this work which is one of its most rewarding features.

Whilst the year has been marked by stimulating new developments it has also been saddened by the departure of old friends and valued colleagues. The death of Professor E. S. Salmon in October, 1959, represents the end of an epoch. A tribute is paid to this distinguished scientist in a special article elsewhere in this report. His many friends in all branches of the Hop Industry are subscribing to commemorate his work by furnishing with suitable dignity a room in the College to be known as the Ernest Salmon Library. Mr. E. G. Cripps has retired through ill health and thereby the College has lost a valued colleague of long standing who was a foundation member of the Hop Research Department. Mr. E. W. Weston after seven years of work on hop chemistry has transferred to the Physical Sciences Department of the College.

New appointments to the Department include Mr. J. B. Roberts who has taken over the Chemistry Section. It is gratifying to record that the Hops Marketing Board has awarded a scholarship to Mr. D. G. Martin for post-graduate research at the College on field problems associated with the mechanical harvesting of hops. Thanks are expressed to Messrs. Arthur Guinness Son & Co. (Park Royal)

Ltd. for generously providing funds for a post-graduate studentship bearing their name which is now tenable at the College and is intended for fundamental research on problems relating to the hop crop.

Grateful acknowledgment is also made to the Agricultural Research Council, the Hops Marketing Board and the Institute of Brewing for unstinted help given throughout the year. Without the financial support and interest of these bodies the Department of Hop Research in its present form could not exist, and we are deeply grateful for their continued encouragement.

DUNSTAN SKILBECK.

July, 1960



Photo: J. Hoed

PROFESSOR E. S. SALMON

PROFESSOR E. S. SALMON

After a long illness, Professor Ernest Stanley Salmon died on 12th October, 1959, at the age of eighty-eight.

WHEN E. S. Salmon entered the South-Eastern Agricultural College in 1906 the practice of defining duties by signed agreements had not been instituted; nor had specialization narrowed the field of a man's studies to the width of a single furrow which the scientific worker of today is likely to plough. Nevertheless, a commentator of the time reported: "A new departure has been made by the appointment of an expert in fungus diseases for the purpose of carrying on research into those diseases attacking more particularly hops and fruit, and Mr. E. S. Salmon, F.L.S., of the Jodrell Laboratory, Kew, has joined the College staff. Mr. Salmon's reputation gives promise that his connection with the College will prove of great value to the fruit and hop growers of Kent and Surrey."

The reputation was based on several outstanding works on mycology, the chief being the classification of an important group of fungi, the *Erysiphaceae*, a group better known to most readers of this article as the "Powdery Mildews". A *Monograph of the Erysiphaceae* was published by Salmon in 1900 at the early age of 29. This scholarly treatise, which must have resulted from the research of several years, remains the standard work on the subject and is still considered fundamental for systematic mycology. It contains over two hundred pages, in which are discussed the characters of the numerous species within the group; also given is an exhaustive list of past records in different parts of the world.

References to economic importance are rare but Hop Mildew *Sphaerotheca humuli* (DC.) Burr., seems to have been given more than its share of attention; not only is a description of the disease added but remedial measures, including the use of sulphur, are advocated. Thus, Salmon's first introduction to the hop was probably through the study of Powdery Mildew at the turn of the century and it is tempting to believe that it was then that he decided to make the plant the main object of future research.

The College opened in 1894 and reports show that investigations on hop problems were begun in the first years. Some of the problems still remain, but it is no longer necessary to explain to the sophisticated husbandman of today that male hops are needed

in the production of new varieties or that seeded cones "grow out" more than those which are unseeded. Yet these features seem to have been a revelation at the time and when Salmon arrived (Sir) Albert Howard had already drawn attention to them and had initiated pilot studies in hop breeding. Howard left Wye for India and Salmon took up the work with enthusiasm. His first two "crosses", made it seems in 1907, were with Fuggles; the male hops used had red and green bines respectively. Of the 85 female seedlings raised, none was of commercial value. The third "cross", with Whites Early Golding, was more promising and ten years afterwards he was able to report that Young Hopeful, his first-named seedling, was being tested for yield "at our Research Station at East Malling and also by a number of hop growers. . . ."

Those who attempt to breed new varieties of crop plants usually have difficulty in determining what characters will be acceptable to the consumer. With hops, this is particularly difficult, for in addition to high yield, disease resistance and other cultural characters required by the farmer, the brewing value of hops is difficult to assess; it does not readily lend itself to exact measurement as quality is based largely on personal opinion regarding the flavour and aroma which a particular hop will impart to beer. Salmon soon decided that a high preservative value was the least nebulous of the properties sought by the "Borough" since this quality might more readily be assessed in the laboratory. His future programme was therefore directed mainly towards producing seedlings with a high content of soft resins.

This being so, it was inevitable that his attention should soon be drawn to American varieties as these were notable for high preservative value but were unsuitable for cultivation in Britain. In 1909, after studying living plants of Oregon Cluster, he concluded that American types of hop differed from those of Europe in enough botanical and other characters to be regarded as a separate species. This led him to revive the name *Humulus americanus* which had been erected by the American botanist, Nuttall, in the previous century. Henceforward, hops of American origin were frequently used either as male or female parents of his seedling varieties.

Salmon's earliest and most notable success with an "English-grown American" was the variety Brewer's Gold. This was of the first generation from an English male hop and a wild hop from Manitoba. Paradoxically, the variety has been more widely grown in Canada and the United States than in Britain. The varieties

Bullion and Northern Brewer which have become so popular with the British hop industry during the past decade are first and third generation seedlings, respectively, of parents from the same sources. The term "English-grown American" was used by Salmon to designate a new variety which he considered had an equal or superior preservative value and a superior flavour to imported American hops. His relations with the more progressive members of the hop industries of America were particularly cordial and Salmon looked forward to the frequent visits made to Wye by them.

In the course of his work Salmon also obtained diverse hop types from countries other than the Americas and these were assembled in his nursery at Wye. They formed an unparalleled collection. From it many thousands of seedlings were produced, mostly to be rejected at an early stage as commercially unsuitable. But a large number survived the severe single plant tests to be passed to East Malling Research Station for a further trial on a plot scale. Records of these may be followed in the annual reports on the "Trial of New Varieties of Hops" which he compiled yearly from 1917-49.

Rarely was a seedling variety given a name until it showed commercial promise; even so, the demands of the industry have been fickle over the years and many of the names will be forgotten except by those few adventurous growers who delighted in having small trial acreages. Among the varieties less widely grown are Brewer's Favourite, Fillpocket, Quality Hop, Brewer's Stand-By, Malling Mid-Season, Southern Brewer, The John Ford Hop, Sunshine Hop and Concord. The last named variety to be described by Salmon (in 1954) was Copper Hop.

The Association of the Growers of New Varieties of Hops was formed on 29th March, 1944, at a meeting of growers at the Star Hotel, Maidstone. The main object of the Association was to render services to the producers and to the consumers (the brewers) of these new varieties. The services were to include the holding of an annual exhibition; the marking of the name of the variety on every pocket; the promotion of chemical analyses of each growth and an endeavour to obtain valuations commensurate with their brewing value. It was pointed out that the Association had come into being through many years of research and selection by Professor Salmon working at Wye College, who had produced the New Varieties.

From small beginnings the Association grew steadily and in 1959 it comprised 129 members; in the same year an estimated total

of more than 1900 acres of New (Wye) Varieties were in cultivation in England or nearly 10 per cent. of the national hop acreage. Two annual events, a walk in gardens of new varieties and an exhibition of the season's growth in the Borough, have not lost in popularity sixteen years after their inception.

In recognition of his work on hops he received from the Institute of Brewing the Horace Brown Medal in 1955.

Those unfamiliar with the Government-sponsored Advisory Service at Wye before World War II might be pardoned for thinking that Salmon's work was concerned entirely with hops. Yet, until his retirement from the post of advisory mycologist in 1937, he was head of the mycology department and responsible for research and for giving advice on diseases of crop plants within the counties of Kent, Surrey and Sussex. It was not long before his name had become a household word among progressive fruit and hop growers. In the first years of the century there was little information on the cause and control of plant disorders, so that at the beginning he was forced to investigate those which seemed to be the more important. His first papers are impressive and include such diverse diseases as the following:

Apple Scab (*Venturia inaequalis*), Pear Scab (*Venturia pirina*), Cherry Leaf Scorch (*Gnomonia erythrostoma*), Cherry Leaf Curl (*Taphrina cerasi*), Leaf Spot of Chrysanthemum (*Septoria chrysanthemella*), Violet Root Rot of Seakale (*Helicobasidium purpureum*), Wart Disease of Potato (*Synchytrium endobioticum*) and American Gooseberry Mildew (*Sphaerotheca mors-uae*).

The last two diseases drew his attention to the need for legislation and the now familiar Destructive Insects and Pests Act became law in 1907 following a vigorous, even violent, campaign which he carried out on the platform and in the press.

The hop, of course, received full attention and in association with his two successive assistants, H. Wormald (1911-23) and W. M. Ware (1924-37), most of the hop diseases we know today were described and investigated to a great or lesser extent. During the first quarter of the century, when Downy Mildew (*Pseudoperonospora humuli*) and Verticillium Wilt* (*Verticillium albo-atrum*) of hops were unknown in Britain, Mould (*Sphaerotheca humuli*) was the most serious fungus disease. Since the application of sulphur was

* Verticillium Wilt was the only important disease of hops which Salmon did not investigate, but the first resistant varieties of hop to be introduced to the grower were from seedlings raised by him.

considered a sufficient cure for this, Salmon's main approach was to ensure that his new varieties were not unduly susceptible to the disease. Selected seedlings were therefore subjected to a test and this was carried out by growing them in a glasshouse which was encouraged to retain infection by a mixture of strains throughout the years.

Downy Mildew had been recorded at Wye by Salmon in 1920 but the newly-introduced disease was not widespread until 1924 by which time the now classic control measures (spike, strip and spray) had been evolved.

Virus diseases, even now barely emerging from the sea of mystery and speculation, were the next to be explored. In 1923, Salmon described Mosaic disease of the hop and distinguished it from Nettlehead with which it had been confused. Within a few years, in association with colleagues, methods of transmitting the viruses by inarching and grafting were evolved. These methods were then used for the routine testing of new varieties so that their reaction to Mosaic, "carrier" or "sensitive", could be determined.

In recognition of his services to mycology and plant pathology, Salmon was elected president of the British Mycological Association in 1911; appointed reader in economic mycology in the University of London in 1912, professor of mycology in 1925 and emeritus professor in 1939. He was made a fellow of Wye College in 1948.

Salmon rarely spoke of himself or of his achievements and those who knew him only during his later days may well have gained the impression that his only interest lay in his work. It is true that he had little time for small talk or for unplanned activities; yet as a young man he had found recreation in diverse pursuits.

Thus, on rare occasions he spoke of participation in the movement for social reform which flourished at the turn of the century while an appreciation of literature remained with him until his last days.

It is doubtful whether he considered field games as a serious pastime but when, at the age of 35, he joined the College staff, he was already an accomplished tennis player and was for some years a pillar of strength to the first six. Perhaps his most impromptu exercise took place when news came that Hothfield Lake was frozen; he would then take down the booted skates from a hook in his room and would soon be on the ice. When nearly seventy, he was seen performing feats of figure-skating which suggested familiarity with winter sports in his younger days.

Uncommon flowering plants fascinated him and he found relaxation in collecting them in his small garden where he managed to find sites for even the more exacting kinds. Colleagues too would occasionally receive a parcel of exotics which had been chosen from a nurseryman's catalogue.

Although Salmon formally retired in 1937 from his appointed post as a plant pathologist, he remained dedicated to his work on hops and this he continued until incapacitated by illness. Until the time of his death a College room was reserved for his use. It is now proposed to perpetuate his memory by furnishing and equipping a research library at Wye College to be known as the Ernest Salmon Library.

A.H.B.
H.H.G.

REVIEW OF RESEARCH

H. S. DARLING

THE problems of hop cultivation have been under investigation at Wye College since this School of Agriculture was founded in 1893. The traditional nature of hop research at Wye entails both advantages and disadvantages. On the one hand it can ensure the continuity of data which is so essential to the success of long-term experiments with a perennial crop. On the other hand it can, unless care is taken, result in the perpetuation of moribund concepts and in a rigid and brittle approach which is inimical to good research. The work described in this report suggests that while exploiting wisely its inheritance from the past, the Department is also developing new lines of work of considerable importance.

Progress in plant breeding research is discussed on page 15. Three new wilt-tolerant varieties bred to replace the Fuggle in wilt areas have gone out into farm trials in the Weald of Kent. These seedlings represent the culmination of the Wye/East Malling Joint Scheme which began in 1950. The final choice of the variety or varieties to be released to the Industry will depend not only on these farm trials, but also on large-scale brewing trials covering three seasons, scheduled to be carried out in 1961-64. New planting material from this source cannot be expected to reach growers before 1965 at the earliest.

In view of the large and costly investment of time, skill and experience necessary for the breeding and testing of a new hop variety, it is encouraging to note that the Hops Marketing Board has set up a small committee of experts to formulate standard conditions for the conduct of farm trials and for the production of hops for brewing trials. This step should help to improve the efficiency of the machinery whereby varieties are assessed and should thus increase the probability of an expensive research programme resulting in a hop that is acceptable to both brewers and growers.

The field experiment programme reviewed on page 18 includes work with clonal selections made from commercial stocks of Fuggles and Goldings. A replicated trial of the former will be harvested experimentally for the first time in 1960. The trial of Golding clones, which was harvested for the second time in 1959,

contains the Bramling clone T9 which may prove to be intermediate in season between the early and mid-season clones. This information, if confirmed, will be of interest to Golding growers in search of that succession of ripening so desirable for efficient harvesting by machine.

The variety trials also include two clonal selections—Spalt and Hallertau—from Germany and two seedlings bred in Denmark by staff of the Carlsberg Breweries. This foreign material has been made available through the Liaison Committee on which the European Brewery Convention and the European Hops Cultivation Committee are jointly represented.

Investigations on hop manuring are mentioned on page 19 and again on page 96. Replicated manurial trials of modern design are being established using as wide a range of soil types and varieties as possible. These trials have as their object the determination of the major element nutrient requirements of the crop under field conditions and the provision of yield data for the calibration of results obtained by routine soil and leaf analysis. A full account of this work to date is being published elsewhere.

Research on downy mildew disease is gathering momentum. This work is discussed in outline on page 27 while certain aspects are treated in more detail on pages 40 and 107. The complex and important problem of the accurate assessment of varietal susceptibility continues to receive attention in support of plant breeding research on the production of resistant varieties. Evidence is accumulating which suggests strongly that downy mildew overwinters as a vegetative mycelium in the rootstocks of infected plants. It is thought that the primary basal spikes which initiate the disease cycle in the spring may arise from dormant buds infected by mycelium growing into them from rootstocks containing the disease. Oospores have not, so far, been shown to be of importance in the overwintering of downy mildew under English conditions.

Hill dusting with Bordeaux powder throughout the growing season reduced the incidence of downy mildew in Golding plants which had been so treated since they were first planted as disease-free setts in 1957. Systemic infection was found in 16-24 per cent. of untreated controls compared with only 1-4 per cent. of treated hills. Research in downy mildew is being continued and expanded and the problems under examination include the method or methods by which rootstocks become infected.

Work on hop propagation has continued. The mist technique has established its value in all branches of hop research. This

method is also arousing interest in connection with commercial hop propagation. Here the problem is to fit an intensive glasshouse technique efficiently into the annual cycle of a perennial field crop. Preliminary work on this problem is described on page 48 where it is shown that soft-wood cuttings rooted under mist in April, May and June were able to grow into satisfactory bedded setts before the following winter. This work is being continued in 1960.

Studies on hop growth are referred to on pages 68 and 98. They include research on the storage and utilization of carbohydrate food reserves in relation to seasonal changes. Preliminary results using setts grown in large pots out of doors indicate that the spring phase of shoot elongation depends largely on food stored in the rootstock for its supply of energy. During the summer food reserves slowly accumulate with a temporary period of depletion in July-August when lateral and cone development are at a peak. In the autumn aerial growth ceases and food accumulation increases rapidly, continuing into late October in spite of the apparently moribund condition of the plant. This work is being extended in 1960 to cover mature plants growing under field conditions.

Research on hop growth has also included preliminary studies on the effect of height of wirework and width of spacing. This work is described in the progress report on the second height of wirework and spacing trial given on page 54. Here yield data for the first season confirmed the findings of earlier work in that they show that increase in yield per plant resulting from wider spacing was insufficient to compensate for the fall in plant population, and yield per acre was therefore reduced. While increase in height from 14 ft. to 16 ft. gave increased yields in all three varieties in the trial, only the vigorous variety Bullion responded favourably to further increase to 18 ft. Examination of bines from the trial suggested that the yield differences observed were reflected in corresponding differences in the numbers of cones produced under the different treatments. These studies are to be continued and extended in 1960.

In this account of the height of wirework and spacing trial mention is also made of a comparison made between hand and machine picking. This comparison was intended primarily to determine the errors resulting from the use of a commercial-type machine for picking small experimental plots. The machine was worked at the lower end of the operating scale recommended by the makers and it was run empty between each plot. The results obtained under the hot dry conditions of September, 1959, with ripe to over-ripe hops were encouraging. Machine picking caused

no loss in yield relative to hand picking and both large and small treatment differences were satisfactorily demonstrated. The comparison is to be repeated in 1960 when it is hoped that observations may also be made with the machine working to full commercial capacity.

The work with the picking machine was carried out in collaboration with the staff of the National Institute of Agricultural Engineering. This collaboration with the Institute includes research on hop drying problems and a summary of the present position with regard to commercial hop-drying installations is given on page 120. It also includes work on the engineering aspects of hop wirework systems and an account of experiments with hop anchors is given on page 82. The standard wood block (dead man) anchor was found to fail at an average maximum load of 7,900 lb. which is well above the yield load of new anchor wire (4,500 lb.). Trials are also in progress in which stresses in wirework systems of different heights are being measured continuously by recording dynamo-meters.

The Department has also collaborated with Guinness Hop Farms Ltd. in a large-scale replicated irrigation trial in progress at Bodiam, Sussex. An interim report on this is given on page 70 from which it will be noted that under the dry conditions of 1959, irrigation gave yield increases of up to 3.1 cwt. dried hops per acre. These results should be accepted with some caution, however, since the site has proved to be unsatisfactory. A new site is being found for the trial in 1960.

Most aspects of hop research depend on chemical analysis at some stage and this work is of great importance to the Department. On page 35 an account is given of methods for resin determination which are in current use at Wye. In future it is hoped in support of plant breeding research to extend the scope of such analytical work to include the examination of cones for essential oils and for the constituent fractions of the alpha acids.

Research on work study aspects of machine picking began in August. This is primarily concerned with the supply of cut bines to stationary machines. It also involves research on the safe and economic disposal of *Verticillium*-infected waste material from machines in wilt areas. The latter work is being carried out in collaboration with East Malling Research Station under the guidance of a working party formed by the Agricultural Research Council to deal with this problem. Preliminary surveys have been made and the results so obtained are being used in planning the 1960 programme of work.

As in previous years, thanks are due to the Ministry of Agriculture, Fisheries and Food for permission to publish summary accounts of the 1959 hop season written by the Hops Advisory Officers in the South East and the West Midlands. These accounts, written by Miss C. L. Jary and Mr. G. P. Chater, appear in Appendices II and III. The hot dry summer of 1959 while favourable to Goldings, adversely affected Fuggle production. It also encouraged powdery mildew which proved difficult to control, especially in Northern Brewer. Progressive Wilt continued to spread and 275 hop farms were officially listed as infected. Five of these represented new outbreaks in the non-wilt areas of North and East Kent.

In Appendices IV and V a survey is given of recent publications on hop research. The official report on the hop experiments at Rosemaund Experimental Husbandry Farm in the West Midlands is reviewed and its findings on a range of controversial subjects are commended to all growers. Work at home and overseas is discussed and the increasing interest taken in hop research in Europe is reflected in the range of papers from Belgium, Czechoslovakia, France, Germany and Russia which are reviewed.

Wye has strengthened its links with this European work during the past year. In March the College was represented at Copenhagen at a meeting of the Liaison Committee of the European Brewery Convention and the European Hops Cultivation Committee. In July staff from the West German Hop Research Organization visited Wye while members of the College in August visited hop research centres in Belgium, Germany and Yugoslavia.

The College has maintained its close and essential connections with the Hops Marketing Board, the Institute of Brewing, the National Agricultural Advisory Service and the Association of Growers of the New Varieties of Hops. Members of the Hop Research Department have served on committees of these bodies including the Hops Working Party and the Advisory Committee of Rosemaund Experimental Husbandry Farm. Co-operation has been enjoyed with East Malling Research Station and the Brewing Industry Research Foundation on projects of joint interest. As indicated above, the Department has collaborated with the National Institute of Agricultural Engineering in research on hop engineering problems.

Personal links between the College and the Industry have been strengthened and lectures have been given to conferences and meetings of growers. Prominent among these conferences was that

held at Wye College in January, 1960, of which an account is given on page 94. It is regretted that visits to the College hop gardens continue to be discouraged on account of the incidence of *Verticillium* wilt.

Thanks are due to Guinness Hop Farms Ltd., and to other growers for their co-operation in providing facilities for various extensions of departmental research. Grateful acknowledgment is also made of help received from friends in the Borough.

The opportunity is taken to thank the N.A.A.S. for help received in the maintenance of quarantine gardens and out-stations in the Cambridge and Stratford-on-Avon areas. Thanks are again due to Dr. H. H. Glasscock for assistance in connection with *Verticillium* wilt and research on downy mildew.

REVIEW OF THE 1959 HOP SEASON AT WYE COLLEGE

H. S. DARLING

THE 1959 growing season was hot and dry with much sunshine. Plant growth and development were generally satisfactory but showed some signs of being limited by drought. This was especially the case in the Fuggle N growing in the height of wirework and spacing trial. Crop yields were similar to those of 1958, established stands of named commercial varieties averaging 20-25 cwt. per acre. Total soft resins were lower than in 1958, though alpha acid content was generally higher. The beta fraction of the Wye Crop was much lower than in 1958. Meteorological data for Wye for 1959 are tabulated below; mean values for the 25 year period 1935-59 are given for comparison.

	Rainfall Inches per month		Sunshine Hours per day		Mean Temperature °F.	
	1959	1935-59	1959	1935-59	1959	1935-59
January ..	2.52	2.97	2.90	1.75	36.8	38.0
February ..	0.05	2.40	2.45	2.50	38.9	38.6
March ..	1.82	1.83	3.55	4.15	45.5	43.0
April ..	2.38	1.59	5.00	5.85	49.4	47.6
May ..	0.90	1.92	8.00	7.00	54.0	52.9
June ..	1.29	1.81	9.10	7.45	59.1	58.6
July ..	2.13	2.23	9.65	6.80	64.0	61.7
August ..	1.22	2.60	7.90	6.30	63.7	61.8
September ..	0.15	2.34	7.65	5.10	61.3	58.2
October ..	2.87	3.18	5.30	3.75	54.7	51.1
November ..	4.44	3.58	2.00	2.15	45.1	44.6
December ..	6.59	3.01	0.95	1.55	43.0	40.3
Total ..	26.36	29.46				

Aphis attack was early and heavy and signs of incipient damage from red spider were noticed. Both pests were satisfactorily controlled by systemic insecticides. Downy mildew caused little trouble. Mould disease was potentially serious and was only controlled with difficulty.

No further outbreaks of Progressive Wilt have been recorded. A hill infected with *Verticillium albo-atrum* was discovered in Withersdane garden. Results of preliminary examination of the fungus by East Malling Research Station suggest strongly that it is of the fluctuating strain. A pathogenicity test is to be carried out by the N.A.A.S. in the summer of 1960.

The hops ripened early. Picking began on 24th August and ended on 18th September. Little rain fell during this period and the crop was harvested in good condition and subsequently proved to be of Grade I quality. The hops weighed badly on drying, in spite of the hot dry season, giving an average ratio of 123 green bushels per dried cwt. The total crop was 220.5 cwt. as compared with 144.5 cwt. in 1958. The increase was due to higher production in Withersdane garden where new plant came into bearing. Details, together with comparable data for 1958 are given below:

		1959	1958
Goldings	..	52.5 cwt.	67.0 cwt.
Fuggle N		25.0 „	4.5 „
Northern Brewer	..	37.0 „	7.0 „
Bullion		53.5 „	10.5 „
Plant Breeding Hops		52.5 „	55.5 „
		220.5 cwt.	144.5 cwt.

The picking machine harvested about 55 cwt. as compared with only 16 cwt. in 1958. Its use was confined largely to the height of wirework and spacing trial.

In the winter of 1959-60 new wirework was erected in the northern half of Withersdane garden over plant established on polework in the previous summer. This new plant includes variety trial plots which replace those grubbed in Wye Field in 1957.

PLANT BREEDING SECTION

REVIEW OF THE YEAR'S WORK

R. A. NEVE and R. F. FARRAR

THE outstanding feature of the year was the distribution for farm trial of three varieties selected from the Wye/East Malling Joint Scheme as potential wilt tolerant replacements of the Fuggle hop. In these trials which are sited on the farms of three hop growers in the wilt area, Whitbread's Golding Variety has also been planted for comparison.

It is of great importance that these trials should result in an accurate estimate of the value to growers and brewers of the varieties concerned, and it is encouraging that both sides of the industry are co-operating to achieve this.

The hops grown in these farm trials will be submitted to the large-scale brewing trials carried out by a number of brewers and organized by the Institute of Brewing. In order to ensure that these hops should reach the brewers in the best possible condition, a committee was set up by the Hops Marketing Board to consider the conditions under which they should be grown and dried. On this committee's recommendation, Fuggle hops grown at Rosemaund in 1959 and 1960 are being dried at three different temperatures and then submitted to large-scale brewing trials. From the results of these trials will be decided the temperature at which the new varieties should be dried when being prepared for brewing trials.

Three other varieties from the same breeding scheme were rejected as Fuggle replacements because of their American aroma. Nevertheless they were thought to show promise as wilt tolerant varieties of the American type, and a single farm trial of these three varieties has been planted by Guinness Hop Farms.

From the polyploid breeding programme a wilt susceptible triploid seedling of Bullion has been released for farm trial in the West Midlands. The planting material for this trial had to come from the quarantine garden, and only a small quantity was available. Much propagation will be necessary, therefore, before the farm trial can be planted. This variety is of interest since not only

is it the first Wye variety raised since the war to be put into farm trial, but it is the first triploid hop to reach this stage. It is of the Bullion type, and will need to show advantages over that variety before it can be considered for release to the industry.

BREEDING PROGRAMME

As a result of tests by the pathologist on seedlings bred for resistance to Downy Mildew, a male seedling was discovered which had a sufficiently high level of resistance for it to be incorporated into the breeding programme. This male was used to pollinate diploid and tetraploid forms of Nonsuch (OB53), a variety that is highly tolerant of *Verticillium* wilt and that has a very high resin content. Although promising female seedlings may result from these crosses, the primary aim is to produce male seedlings that can transmit wilt tolerance, Downy Mildew resistance and high resins to future generations of seedlings.

Initially the level of Downy Mildew resistance that can be combined with all the other characters essential for a successful new variety will probably not be very high, but in the course of time it is hoped to attain a level where spraying becomes almost unnecessary. Even a low level of resistance will be a great advance on some of the varieties at present in cultivation, in which it is difficult to control the disease, even with a full spraying programme.

The work of breeding for tolerance to *Verticillium* wilt continued and approximately 1,000 triploid and 500 diploid seedlings from Golding, Hallertau and Saaz hops, pollinated by wilt tolerant males, were raised and planted out.

So far triploid seedlings have all been raised from tetraploid forms of wilt susceptible varieties, but the tolerant Whitbread's Golding Variety was successfully treated with colchicine and will be used in the 1960 breeding programme. A wilt tolerant male (OB79) was also treated with some success.

RESEARCH PROGRAMME

In order to compare the wilt tolerance of diploid and triploid seedlings, tests were carried out at East Malling on seedlings from the crosses: diploid Eastwell Golding $\times$ OB79 and tetraploid Eastwell Golding $\times$ OB79. From each family 112 seedlings had been propagated in 1958 and three plants of each seedling variety were submitted to wilt test in the summer of 1959. By September, 70 per cent. of the triploid plants showed wilt symptoms, compared

with 39 per cent. of the diploid plants. The greater susceptibility of the triploids was not unexpected, but further testing of the most tolerant seedlings at the 30-plant level will be necessary before the full implications of this result can be assessed.

The inheritance of resin characters in diploid and triploid families was examined by carrying out resin analyses on 120 seedlings from each of the same two families used for the wilt test. The seed content of each sample was also determined and the resin analyses corrected to a seed-free basis so that a valid comparison could be made between the two families. The mean resin content of the seedlings was higher than that of the Eastwell Golding parent, confirming earlier indications that male OB79 transmits high resin values to its seedlings. The increase in the beta fraction was greater than the increase in alpha acids as shown by the following figures which are corrected to a seed-free basis. The uncorrected figures are shown in brackets.

*Increase in mean resin content of seedlings over
Eastwell Golding controls*

	<i>Diploid Family</i>	<i>Triploid Family</i>
alpha acids	13% (10%)	20% (46%)
beta fraction	57% (61%)	46% (78%)
total soft resins	31% (34%)	30% (59%)

The mean values for seed content were: triploid family 3.1 per cent., diploid family 19.0 per cent. and Eastwell Golding 20.2 per cent. The seedlings were in their second season and Mr. Farrar's investigations into the seed content of diploid and triploid hops, described elsewhere in this report, suggest that there may be a slight increase in these values as the plants mature.

FIELD EXPERIMENTATION SECTION

REVIEW OF THE YEAR'S WORK

F. C. THOMPSON and F. H. BEARD

GENERAL

The section has continued to assist the Head of the Department in the general management of the commercially grown hops at Wye. An account of the growth of the crop from this aspect, is given on page 13.

Mr. Thompson continued to serve as a member of the Hops Working Party of the N.A.A.S. and of the Scientific Commission of the European Hops Culture Committee. He represented the Scientific Commission at the second meeting of the European Brewery Convention Hops Liaison Committee, held in Copenhagen in March, 1960.

Extra mural duties included a paper read by Mr. Thompson on recent research in hop manuring, at a Conference of hop growers held in Hampshire.

Papers published by the section are referred to on page 144.

HEIGHT OF WIREWORK AND SPACING TRIAL

Records of crop yield, from each of the three varieties in this trial, were taken for the first time in 1959. The trial was also used to investigate the picking of experimental plots by machine. A report on this experiment is given on page 54.

TRIAL OF GOLDING CLONES

Crop yield and other data were recorded for the second year.

With the early clones, the results for the two years indicate that of the eight strains of Early Bird and Bramling under test, to date only Early Bird A4 and Bramling T9 differ appreciably from the others, A4 being consistently higher in resins and T9 later in season. A4, however, is a relatively poor cropper, the mean yield in 1959 being 18·37 dried cwt. per acre compared with 21·19 to 22·18 cwt. per acre for the other three Early Bird clones. T9,

which is a vigorous growing clone, nevertheless cropped badly in 1959 (mean yield 16·08 cwt. per acre compared with 19·07 to 20·78 cwt. per acre for the other three Bramling clones) and it may be that it will have to be harvested later than the other early clones to get a true assessment of its cropping capacity.

It is possible that T9 may prove to be a useful clone to bridge the gap between the early and later clones.

In contrast to 1958, the early clones showed no correlation between yield and resin content. On market valuation the Early Bird clones were preferred to the Bramlings.

Among the 15 later clones under test, yields ranged from 21·11 to 26·04 dried cwt. per acre. Cobbs A9 again gave the highest yield and good resin content, but was not outstanding on market valuation. Mathon 3/91 yielded well, maintained a high resin content and again received favourable comment on the market; Rodmersham B1 also maintained a good all-round performance. Of the remaining clones, Canterbury Golding B9 was outstanding on market valuation and maintained a high resin content but gave a relatively poor yield—21·14 cwt. per acre. As with the early clones, there was no correlation between yield and resin content.

TRIAL OF FUGGLE CLONES

The replicated trial of 11 Fuggle clones was successfully established in Withersdane Garden. Records of crop yield will be taken in 1960.

EUROPEAN BREWERY CONVENTION: HOPS LIAISON COMMITTEE VARIETY TRIALS

An observation trial is being established in Withersdane Garden, to compare the growth and cropping of selected Danish, English and German varieties under comparable conditions. The varieties are Nordgaarden Seedlings S978 and S1478, bred by Professor Winge; Fuggle N and Northern Brewer; Hallertau and Spalt clones selected by Professor Zattler. Similar trials are being established in experimental hop gardens in Denmark and Germany.

FIELD MANURIAL TRIALS

The long-term manurial trial laid down at Bodiam, Sussex, in 1949, to study the high-level manuring of hops has been completed and a paper embodying the results has been accepted for publication (*J. Hort. Sci.*, 1960; **35**, 185).

Lower levels of manuring are now being tested in the new series of 3^3 NPK trials established at Teynham, Kent and Bodiam, Sussex, in 1958/59, on soils containing different levels of available nutrients. The varieties involved are Bullion at Teynham and Keyworth's Mid-season and Fuggle at Bodiam.

At Teynham (Norton West) the soil, a brickearth overlying chalk, is extremely high in both available phosphate and available potash, and the contents of soil organic matter and nitrogen are also high. Under these conditions the highest yield responses have been obtained with the lowest levels of NPK manuring.

On the first site at Bodiam (Shinmore), the soil is also of brick-earth type but overlies Tunbridge Wells Sand. Available phosphate and potash are very high in the top soil but fall to low to medium in the sub-soil, while soil organic matter and nitrogen are relatively low. In this trial there has been some response to the higher levels of nitrogen and phosphate manuring tested, but in the case of phosphate this may be due, in part, to the rather high rate of replanting on this site, and the known response of young plants to phosphate. The variety here is Keyworth's Midseason and the loss of plants due to Downy Mildew infection of the rootstock, and other causes, has resulted in a very variable plant population in this trial, to such an extent that it has been decided to abandon the trial in favour of another site.

On the second site at Bodiam (Stainsmore), the soil is again of brickearth type overlying Tunbridge Wells Sand, but contains somewhat lower levels of available phosphate and potash than the Shinmore soil, though the contents of soil organic matter and nitrogen are higher. On this soil there has been little or no response to the higher levels of nitrogen and phosphate manuring, but a useful response to the medium level of potash.

A further 3^3 NPK trial has been established at Wye, in Withers-dane Garden. The treatments were applied in Spring, 1960, and records of crop yield will be taken in September, 1960.

Work on the mineral deficiency plots at Goudhurst, Kent, was completed and a report published (*Rep. Dep. Hop. Res. Wye Coll. for 1958*, 40).

Results from the magnesium deficiency observation trial at Beckley, Sussex, on soil very low in available magnesium, showed that applications of magnesium sulphate had no beneficial effect on the market valuation of the crop, thus confirming the previous year's findings. On the other hand there was an indication that applied magnesium had increased the resin content of the cones.

Leaf and soil samples for mineral nutrient analysis, and cone samples for resin analyses, were collected from all the trial plots as in previous years. In addition, leaf and cone samples from the hop manurial trial at the Rosemaund Experimental Farm, were analysed.

The observation trial on the growth of hops in grass was maintained and produced fair growth and crop. The hops were irrigated in 1959.

CHEMISTRY SECTION

REVIEW OF THE YEAR'S WORK

E. W. WESTON

SYSTEMIC CHEMICALS

Hops growing under ordinary field conditions were treated with pentachlorophenoxyacetic acid, benzoic acid, urea and dimefox, in a similar manner to that which was employed in the previous year. A small quantity of the first mentioned chemical was synthesized for the purpose.

Owing to the weather, no downy mildew spikes developed nor was there any appreciable incidence of powdery mildew in the plot concerned so that resistance of the treated plants to these diseases could not be estimated. Yields of cones were measured and resins were determined. Samples of leaves and cones were taken for inorganic analysis and also for the determination of reducing sugars; these are at present being examined.

SAND CULTURE EXPERIMENT

An experiment was carried out with hop plants grown in sand culture. Treatments comprised different levels of phosphate applied in solution, together with an otherwise complete nutrient solution. Samples of cones were taken for measurements of yield, percentage resins, and percentage reducing sugars. Results are not yet available but will be published in due course.

STORAGE EXPERIMENT

An investigation was carried out with kiln-dry hops of mixed origin kept in the dark at room temperature to determine which of four storage methods available gave the minimum loss of resins. The methods examined were:

- (a) Loose hops in muslin bags: 50 g. per bag.
- (b) Loose hops in tightly closed small polythene bags: 50 g. per bag.

(c) Hops pressed in a box mould for 12 hours at 0.25 kgm. per sq. cm. ($3\frac{1}{2}$ lb. per sq. in.) to form 10 cm. cubes weighing 200 g. each; each cube was tightly wrapped in brown paper as soon as it was removed from the mould.

(d) Hops highly compressed at 160 kgm. per sq. cm. (1 ton per sq. in.) to form cylindrical pellets 7.5 cm. in diameter and 3.75 cm. thick weighing 100 g. each. All pellets were stored together in a tightly closed polythene bag.

The experiment started with newly-picked hops in September, 1958, and ended in March, 1959. Analyses for resins were made at intervals by the normal petroleum ether extraction method described on page 35 of this report. Results are tabulated below.

ALPHA ACIDS AS A PERCENTAGE OF OVEN-DRIED HOPS

Date of analysis	Method of storage			
	Polythene bag	Muslin bag	Pressed box sample in brown paper	Compressed pellet
October 21st, 1958 ..	5.57	5.61	6.17	5.09
	5.98	6.48	5.97	5.26
December 15th, 1958 ..	5.25	5.47	5.33	4.82
March 6th, 1959 ..	3.91	3.79	4.14	3.21
	3.85	3.75	4.11	3.25
Percentage loss ..	67.2	62.4	68.0	62.4

TOTAL SOFT RESINS AS A PERCENTAGE OF OVEN-DRIED HOPS

Date of analysis	Method of storage			
	Polythene bag	Muslin bag	Pressed box sample in brown paper	Compressed pellet
October 21st, 1958 ..	12.77	12.71	14.08	13.83
	13.61	14.73	13.67	14.26
December 15th, 1958 ..	11.89	12.10	12.05	13.16
March 6th, 1959 ..	9.41	8.70	9.93	9.66
	9.03	9.24	9.46	9.59

These results suggest that there was little difference between the methods used except that high compression caused an initial rapid loss of alpha acids (but not total soft resins) as shown by the

analyses made on October 21st, 1958. This initial high rate of loss of alpha acids in the heavily compressed samples was not maintained and from November onwards all treatments showed the same rate of loss.

ROUTINE ANALYSES

Further analyses for starch and sugar in hop roots were carried out in support of physiological studies on the development and growth of the hop plant.

Over 1,000 analyses of 830 samples for hop resins were carried out during the year in support of research in the Department and elsewhere.

ENTOMOLOGY SECTION

REVIEW OF THE YEAR'S WORK

H. S. DARLING

A replicated trial was carried out to investigate the effect of derris and the systemic insecticides demeton methyl and dimefox on aphid populations (*Phorodon humuli*), on crop yield and on the ratio of green to dried hops. This was a repetition of a trial made in 1958 (Darling and Beard, 1959), the same mature stand of Petham Golding hops being used in a randomized block lay-out. The treatments were replicated five times, each plot consisting of 30 hills of which 12 were recorded and 18 were discards. The plants were grown on the square at a spacing of 6 ft. 6 in. (2 metres) with upright umbrella stringing on wirework 14 ft. 6 in. (4.35 metres) high.

Derris was applied 9 times as a high volume spray from 28th May to 31st July. Demeton methyl and dimefox were soil applied four times and three times respectively during the same period at the rate of 0.25 gm. per plant in 120 ml. water per application. At each application of the derris spray the other treatments were similarly sprayed with water only.

Counts were made during the season of leaves showing established aphid infestations. On 28th May, immediately before the first application of insecticides, all treatments showed more than 90 per cent. of leaves infested. Nine counts made during June and July gave the following average results:

Derris	68% (21%-93%)	leaves infested
Demeton methyl	8% (1%-19%)	„ „
Dimefox	8% (0%-28%)	„ „

Examination of leaves in August and ripe cones in September showed that while a small residual population of aphids persisted in the derris plots, the two systemic treatments were free from infestation.

The trial was harvested by hand under good conditions on 7th September. Yields of dry hops (10 per cent. moisture content) were as follows:

Derris	19.07 cwt. per acre
Demeton methyl	20.88 " " "
Dimefox	21.33 " " "
Least sig. diff. ($P = 0.05$)	1.62 " " "

Both systemic insecticides significantly out-yielded the derris treatment. As in 1958 the dimefox treatment out-yielded the demeton methyl, the difference being non-significant at $P = 0.05$.

Resin analyses gave the following average results:

	<i>Alpha Acids</i>	<i>Total Soft Resins</i>
	%	%
Derris	5.94	10.34
Demeton methyl	6.25	10.75
Dimefox	5.70	9.78

These resin values fall within the expected range for Golding hops.

Ten bushels from each treatment were dried separately and the resulting hops weighed. The following average results were obtained:

	<i>Weight of dry hops/bushel</i>	<i>Bushels/dried cwt.</i>
Derris	440 gm.	115.5
Demeton methyl	441 gm.	115.3
Dimefox	416 gm.	122.2

The difference between dimefox and the other two treatments approached significance at $P = 0.05$.

PATHOLOGY SECTION

REVIEW OF THE YEAR'S WORK

J. R. COLEY-SMITH and F. H. BEARD

THE work of this section has been entirely concerned with Hop Downy Mildew disease (*Pseudoperonospora humuli*).

(a) HILL DUSTING OBSERVATION TRIAL

This long-term hill dusting trial, now in its third year, has been continued. Golding setts were planted in March, 1957, in ground from which hills known to be heavily infected with the disease had recently been grubbed. The treatments applied in 1957 and 1958 were repeated in 1959 and are being continued in 1960. These consist of captan dust or Bordeaux powder applied from a bag to individual hills at approximately monthly intervals as follows:

(1) Three times per season during April-June (Bordeaux powder only).

(2) Six times per season April-September (Bordeaux or captan).

(3) Untreated controls.

Dusts were applied at the rate of 15-20 lb. per acre (6.5-9.0 gm. per hill) per application.

In 1958 all hills showed the characteristic freedom of young plants from Downy Mildew in the rootstock and from basal spikes. Results for 1959 are summarized below.

All the dusting treatments were effective in protecting hills from infection by Downy Mildew disease. Captan dust was less effective than Bordeaux powder and this material is not being considered for further trials. Bordeaux powder applied throughout the growing season was the most effective of the treatments. It must be emphasized that this trial was started with healthy planting material. There is no reason to suppose that dusting would be effective in a garden with a high proportion of hills systemically infected by Downy Mildew disease.

In view of these encouraging results three further experiments have been started. Two of them are in the departmental hop

TABLE 1

Treatment	Early clones (80 hills/treatment)				Late clones (150 hills/treatment)			
	% total strap cuttings infected	% hills with infected strap cuttings	% hills with basal spikes	Number of basal spikes per hundred hills	% total strap cuttings infected	% hills with infected strap cuttings	% hills with basal spikes	Number of basal spikes per hundred hills
Bordeaux powder applied early only	2.0	6.3	10.0	31.3	1.3	4.7	10.0	38.0
Bordeaux powder applied throughout season	1.1	4.1	6.3	16.3	0.2	1.3	6.7	18.7
Captan powder applied throughout season	6.8	10.1	12.5	31.3	1.6	4.7	8.0	27.3
Control. Not dusted	10.6	22.5	26.3	153.8	5.3	16.0	38.7	208.0

gardens, a fully replicated trial involving hand dusting, and another non-replicated trial in which the dusts will be applied by machine. The third experiment will be carried out on a commercial grower's farm in conjunction with the N.A.A.S.

(b) OVERWINTERING OF HOP DOWNY MILDEW

Research has continued on the problem of how the first infected shoots (basal spikes) arise in the spring. Results are fully discussed in an article on page 107 of this report.

(c) DOWNY MILDEW RESISTANCE TESTS

Methods used for testing leaf and shoot resistance of hops to Downy Mildew disease are described on page 40 of this report.

CROP PHYSIOLOGY SECTION

REVIEW OF THE YEAR'S WORK

I. H. WILLIAMS

GROWTH STUDIES

Fundamental studies on the growth and development of the hop were continued. Changes in the pattern of development at different seasons of the year were measured using dry weight of different organs of the plant as an indicator.

DORMANCY AND FOOD STORAGE

Changes in the food storage levels of young plants grown in pots in the open were examined. The reserves in the rootstock accumulated in the autumn and appeared to be important in overwintering and in supplying energy for shoot growth in the following spring. This work is described fully elsewhere on page 98 of this report.

PROPAGATION

A series of experiments were carried out to establish methods of growing hops at different times of the year to supply material for the propagation of soft-wood cuttings. A preliminary trial was carried out to assess the development of rooted soft-wood cuttings planted in the field at different times during the growing season. These experiments are described in detail on page 48 of this report.

HEIGHT OF WIREWORK

Preliminary growth studies on a few hills growing under different conditions of height and spacing were carried out. This indicated that both height and spacing influence the form of development and yield of the plant. A brief note on this has been included with the general data on this experiment on page 68.

IRRIGATION

The irrigation experiment at Bodiam, carried out with the co-operation of the Guinness Hop Farms Ltd., was repeated in 1959. Increased yields were obtained on the irrigated plots. This experiment will be continued for a number of years. An interim account of this work is given on page 70 of this report.

A NOTE ON THE BORON NUTRITION OF THE HOP

E. G. CRIPPS

A FULL account of earlier experiments carried out by the author on the boron nutrition of the hop has already been published (Cripps, 1956) and this note summarizes the findings of this and later work up to and including the 1958 season when the experiments were concluded. In the work previously reported the symptoms of boron deficiency and toxicity developed in sand-culture were described, and the results were given of experiments on seasonal variation in the boron content of the hop leaf. It was found that boron increased in the leaves with maturity, and further, that there was no return of boron from the aerial parts of the plant to the rootstock on ripening. In addition, an account was given of a field trial in a hop yard in Hereford, where plants showing symptoms corresponding to those found with boron deficiency in sand-culture, responded to treatment with borax.

Later work has been concerned with the influence of boron nutrition on the resin content of the hop cone, but the claims made by some overseas workers that applications of borax can increase resin content, have not been substantiated in England.

In addition, a soil-culture experiment in barrels was carried out using three soil types—clay, brick earth and sandy loam. Borax applied at the rate of 24 lb. per acre proved to be excessive and toxicity symptoms developed in the plants in all three soils, though the symptoms were markedly less in the clay soil. In the following year, after thorough leaching by the winter's rains, the hops in the brick earth and sandy loam showed greatly improved growth, but toxicity symptoms still appeared in the clay soil.

A further experiment was concerned with the effect of using a proprietary boron spray on boron-deficient plants grown in sand-culture. The results obtained showed that boron applied in this way was absorbed into the plant and translocated, to some extent, to younger growing tissue but not to older tissue. As boron present in the aerial parts of the plant is not returned to the rootstock, spraying to control boron deficiency can only be regarded as a temporary measure.

CONCLUSIONS

There is no doubt that boron deficiency can arise in hops in the field, and its occurrence has been reported in Germany (Zattler, 1942, 1958) and in New Zealand (Askew and Monk, 1956).

In England there are a few hop gardens where symptoms strongly indicative of the deficiency have appeared in some seasons. With one or two exceptions these outbreaks have been confined to hops growing on soils derived from the Old Red Sandstone in Hereford, on which susceptible crops readily develop boron deficiency, particularly when the soil is over-limed. The affected plants have occurred either singly, or in small groups, and no cases are known where the whole hop yard has been affected. There is some evidence that plants showing the symptoms have responded to soil treatment with borax.

The deficiency is markedly seasonal in its onset and, in Hereford, plants which have shown severe symptoms in one year have been found to produce relatively normal growth in the following year, though receiving no boron treatment. In view of the limited and spasmodic way in which the deficiency occurs in hops, it must be stressed that the trouble is of little economic importance in this country at the present time.

Applications of boron compounds should only be made after consultation with the Hops Advisory Officers and, where possible, confirmation of the deficiency by leaf and soil analyses. The material commonly recommended for soil treatment is borax (sodium borate), and with hops the rate of application should not exceed 10 to 15 lb. per acre. If this rate is exceeded there is a serious risk of inducing boron *toxicity* which can kill the plants, and in fact may be far more devastating in its effect than boron deficiency, particularly on heavy soils from which borax is not readily leached out.

As it is virtually impossible to achieve an even spread of borax at 10 to 15 lb. per acre, it is usual to dilute the material with a large bulk of sand or other filler, but even with this precaution there is still a risk of applying too high a concentration of borax in localized patches. Probably the safest way to apply boron is to use one of the proprietary boronated fertilizer compounds which are now marketed for use on root crops such as sugar beet and swedes—crops which are particularly susceptible to boron deficiency.

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METHODS OF ANALYSIS FOR HOP RESINS AT WYE COLLEGE

E. W. WESTON

SUMMARY

An account is given of the methods used at Wye College for analysing hops for resins. Ground hops are normally extracted with petroleum ether, the resulting solution evaporated and its residue extracted with methanol. From the methanol extract, total soft resins are determined by evaporation and alpha acids by polarimetry; the beta fraction is determined by difference. Results are comparable with those obtained by the standard Ford and Tait method.

INTRODUCTION

The Department of Hop Research at Wye College carries out analyses for resins on several hundred hop samples each year. Two people are normally occupied on this work from hop picking time in September until the middle of January. The methods of analysis are based on those described by Ford and Tait (1932) to which modifications have been made only when they led to definite improvements in terms of accuracy or ease of manipulation.

Two methods of resin extraction and subsequent determination are used and are described below. One employing diethyl ether extraction as in the original Ford and Tait method, is used for the samples submitted by the Institute of Brewing in connection with the New Varieties Challenge Cups competition, in order to maintain continuity in these analyses from year to year. The second, using petroleum ether extraction, is used for all other samples. The analytical technique for the two methods differs only in the total soft resins determination.

When the initial extraction of the resins is made with petroleum ether, 24 samples can be analysed for both alpha acids and total soft resins in the course of a day. The time taken for a single analysis thus compares favourably with the time for a single alpha acid analysis using the conductimetric "rapid" method.

Samples are not normally analysed in duplicate since it is usual for the experiments from which the samples are derived to include replication in their design. Where individual analyses are required with accuracy, these analyses are duplicated and are repeated if not agreeing within 5 per cent.

EXPERIMENTAL

Sampling

Pending analysis, samples were stored at room temperature in the following ways:

- (a) As kiln-dry loose hops in airtight 2 lb. Kilner jars. The whole of the sample was ground on the day of analysis and returned to the Kilner jar to await extraction. This sample was normally only a little over 20 g.
- (b) As kiln-dry loose hops in polythene bags fastened with rubber bands. A sufficient quantity of the sample was ground on the day of analysis (20-50 g., see note 1) and placed in a Kilner jar to await extraction.
- (c) As pressed kiln-dried hops in pocket or box samples. These were either 4-inch cube samples cut from a pocket or small samples pressed for 24 hours in a box mould and then packed in such a way as to simulate those cut from a pocket. They were normally wrapped in thick brown paper.

A half-inch layer was cut from the outside of the sample across the grain, and rejected. A further similar layer weighing approximately 30 g. was cut, ground on the day of analysis and transferred to a Kilner jar as before.

In (a) and (b) above, the samples were relatively free from leaf and stem. This was not necessarily the case in the pocket and pressed samples in (c) and here large pieces of leaf and stem and other extraneous matter were normally removed before grinding. Where the degree of contamination was a valid treatment effect, e.g. in machine picking experiments, the whole portion was ground.

Grinding

All samples were ground before analysis. Grinding was originally done in a domestic mincing machine which was slow and laborious when large numbers of samples were to be ground. The frictional heat developed was considerable and on occasions over-vigorous grinding resulted in a charring of the hop material and caused the mincer to seize up completely.

A number of electrical grinders were examined but apart from one or two large models whose cost was prohibitive, there were in each case difficulties with the feeding system, overheating, low through-put and blocked outlet screens.

The Hillman coffee mill finally selected removed or reduced most of these difficulties, and was cheap enough to allow two to be operated alternately thus reducing heating troubles. The grinding was continued long enough to give a fineness roughly equivalent to the hand mincer; a more finely ground material would not allow proper percolation of solvent during the extraction.

Determination of Moisture Content

Samples for analysis were received in kiln-dried condition usually containing 6-12 per cent. moisture. The percentage dry matter was determined as follows: an accurately weighed approximately 1 g. portion of the ground cones was dried by heating in an open dish in an oven at $100^{\circ} \pm 0.5^{\circ}$ C. overnight. The sample was allowed to cool in a desiccator and reweighed. The loss in weight was expressed as a percentage of the original sample weight.

Preparation of Resin Extract

An accurately weighed 13.33 g. sample of ground cones was packed lightly into a soxhlet extractor and extracted exhaustively with either diethyl ether or petroleum ether. The extraction was continued for approximately two hours (note 2). The solvent was then removed from the extract by distillation from a water bath at 60° C. with solvent recovery (note 3). The treacly residue was taken up in methanol (note 4) leaving the wax as an insoluble sludge. The suspension of wax and methanol extract was quantitatively transferred to a 100 ml. volumetric flask and made up to the mark with methanol. The suspension was then filtered through a Whatman No. 4 paper and the clear filtrate used for subsequent analysis. This solution is referred to below as the "methanol extract".

Determination of Alpha Acids

The method used was the same irrespective of the solvent used for the initial resin extraction.

The methanol extract, after a 15 ml. sample had been taken for determination of total soft resins (see below), was treated with approximately 0.5 g. of decolorizing charcoal (note 5), and filtered through a Whatman No. 1 paper into a clean dry flask. The cleared extract was run into a 20 cm. polarimeter cell and the optical rotation measured using light from a sodium discharge lamp. Repeated observations on the same solution normally did

not vary by more than 0.02° but if the extract was highly coloured, insufficient light passed through the cell to enable this precision to be obtained, and a 10 cm. tube was used. The rotation was thereby halved and some loss of accuracy was accepted. Initial extraction with petroleum ether gave solutions with much less colour than did extraction with diethyl ether, so that since the methods agreed within sampling and experimental error, petroleum ether was to be preferred.

For a 20 cm. cell.

$$\text{Percentage alpha acids} = \frac{\text{Angle of rotation} \times 1.821 \times 100}{\text{percentage dry matter of hops}}$$

Determination of Total Soft Resin

The method employed depended upon the solvent used for the initial extraction, since diethyl ether dissolves hard resins as well as soft resins; the latter being defined as those resins soluble in petroleum ether.

(a) After initial extraction with diethyl ether.

A 15 ml. sample of the methanol extract was pipetted into a separating funnel containing 30 ml. of 1 per cent. aqueous sodium chloride solution and the mixture extracted five times with portions of a 200 ml. total volume of petroleum ether using the method of Ford and Tait (1932). The extracts were filtered through a Whatman No. 4 paper, the paper washed with petroleum ether and the combined filtrates and washings evaporated in a weighed flask from a water bath at 60°C . The outside of the flask was carefully dried with a clean cloth and the last traces of solvent removed by heating in an oven at 100°C . for 3 hours (note 6). The flask was reweighed after cooling for at least an hour. When the prescribed weights and aliquots were taken for analysis, the percentage total soft resin was given by

$$\% \text{ T.S.R.} = \frac{\text{weight of resin}}{2 (\% \text{ dry matter of hops})} \times 100$$

(b) After initial extraction with petroleum ether.

The 15 ml. sample of the methanol extract was pipetted directly into a weighed 250 ml. flask, and the methanol evaporated on a water bath. The residue was then dried and weighed as above, and the total soft resin percentage calculated in the same way (note 7).

Notes

(1) A sample size for grinding of about 50 g. was considered adequate to ensure that sampling errors were not excessive. If samples of less than 20 g. were taken, the sampling error was probably the major one.

(2) In the original Ford and Tait method it is suggested that at least 12 percolations should be made and this normally takes about an hour.

(3) Although the ether used originally was of AnalaR grade and presumably free from water, alcohol, aldehydes and peroxides, the redistilled ether must have been contaminated with most if not all of these. No differences in resin analyses were noticed when redistilled ether was used so that no further purification was carried out.

(4) The method described by Ford and Tait involves the removal of the last traces of ether at a vacuum pump. This, apart from being tedious, led in many cases to the formation of a hard residue which could only be dissolved in methanol by heating. The normal practice adopted was to leave a little of the solvent such as remained after distillation over a water bath at 60° C.; this made no detectable difference to the final resin analyses.

(5) Sutcliffe and Speakman quality NY3/6W. Other grades of charcoal were only used if tests indicated that no appreciable amount of alpha acids was absorbed under these conditions.

(6) The values for total soft resins were not changed when the flasks were left in the drying oven overnight, but no check on the minimum time of drying was made.

(7) When the petroleum ether extraction was used and the methanol extract obtained submitted to the same purification as if diethyl ether had been used for initial extraction, the analyses were always too low. With the described methods results were consistent in most cases.

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TESTING HOP VARIETIES FOR RESISTANCE TO DOWNY MILDEW DISEASE *PSEUDOPERONOSPORA* *HUMULI* (MIY. AND TAK.) WILSON

I. PRELIMINARY DETACHED LEAF AND SHOOT TESTS

J. R. COLEY-SMITH

SUMMARY

Preliminary detached leaf and pot plant methods for testing resistance of hop varieties to downy mildew disease are described.

INTRODUCTION

The production of hop varieties resistant to downy mildew disease forms part of the current programme of breeding work which is being carried out in this Department. In the past, selection has been based entirely upon field performance but in view of the large numbers of seedlings which usually have to be assessed in the production of a hop with desirable commercial qualities, quicker and more reliable methods are required by which plants can be screened for resistance to this costly disease. In addition methods are sought by which comparisons of levels of leaf, shoot, cone and rootstock susceptibility can be made, since resistance in all these parts of the plant is of great importance.

MATERIALS AND METHODS

No hop variety is known which is immune to downy mildew disease, but there is a wide range in the degree of field resistance shown by different varieties. At the beginning of this work five varieties were selected for experiment which were thought, as a result of observations made in a small-scale field plot, to possess different levels of field resistance. Two of these, Eastwell Golding and Fuggle N, are standard commercial varieties; CC77 is a variety bred at Wye (Beard and Salmon, 1954); 2L118 is a resistant hop obtained from Professor F. Zattler of Munich, and 16/54/14 is a seedling derived from an open pollinated plant of 2L118. These varieties apparently ranged from extreme susceptibility to a high degree of resistance in the order Eastwell Golding, CC77, Fuggle N, 16/54/14 and 2L118.

In the work described in this paper no account has been taken of the possibility of the occurrence of physiological specialization in *Pseudoperonospora humuli* but now that sufficiently standard methods are available this will be investigated. Suspensions of sporangia were obtained from a single isolate of *P. humuli* maintained on pot plants of Eastwell Golding. The sporangia were washed off the leaves with distilled water and their concentration standardized by means of haemocytometer counts followed by the appropriate dilution. Suspensions were always used just after zoospore emergence.

DETACHED LEAF TESTS

The advantage of a detached leaf method for testing varietal resistance lies in the fact that seedlings which are required for reasons other than downy mildew resistance are not sacrificed as a result of the test. Several methods have been investigated for the incubation of leaves during the test period. The method most used has been that of Hoerner (1942) in which zoospore suspensions were atomized on to the lower surface of leaves placed in petri dishes lined with moist filter paper. This method has the disadvantage that rotting of leaves sometimes occurs within the pre-sporulation period. A method which shows considerable advantages over the Petri dish technique has recently been used. This consists of placing the petiole of the detached leaf in a tube containing distilled water followed by incubation in a humidity chamber. With this method rotting of leaves does not occur within the pre-sporulation period.

Density of sporulation was found to give the most reliable estimate of leaf infection. This was measured as the number of sporangia produced per unit area of leaf surface (sporulation only occurs on the lower leaf surface). In order to measure leaf areas contact prints were obtained on light-sensitive paper and traced with a planimeter. All detached leaf tests were carried out at approximately 20° C. Leaves used in these tests were obtained from plants grown in pots.

During preliminary trials detached leaf methods gave variable results. This variation has been ascribed to two main causes, leaf age and inoculum concentration.

Age of Leaf

Leaves were detached from five successive nodes of shoots from pot plants of Eastwell Golding. At node 1 (youngest) the

leaves were only slightly expanded. At node 2 they were almost fully expanded and at node 3 were completely so. Ten leaves of each type were taken. Density of sporulation was measured five days after inoculation. Results are shown in Fig. 1.

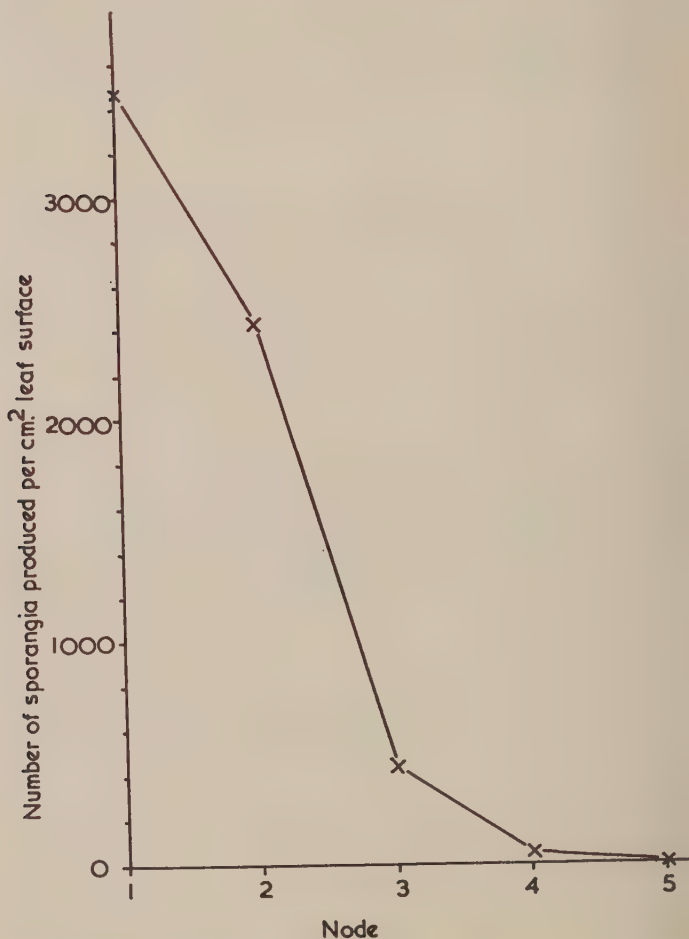


FIG. 1

The relationship between age of leaf and infection of detached leaves of Eastwell Golding by *Pseudoperonospora humuli*.

The amount of infection obtained was greatly influenced by the age of the leaf, the youngest leaves being most susceptible. In subsequent tests leaves corresponding to node 2 in this experiment were chosen. These were considered to be the most suitable type as regards size and susceptibility.

Inoculum Concentration

A sporangial suspension was standardized at 50,000 sporangia per ml. and dilutions were made from this. The suspensions were used to inoculate detached leaves of Eastwell Golding (10 per treatment). Sporulation density was measured five days after inoculation. Results are shown in Fig. 2.

The amount of infection increased with increasing inoculum concentration up to near maximum at 10,000 sporangia per ml. Above this concentration there was little further increase in the degree of infection.

Hop Variety

By using a standard concentration of sporangia (20,000 per ml.) and age of leaf the five hop varieties showing a differential field response to downy mildew infection were tested. Ten leaves of each variety were used. Daily sporing rates (Fig. 3) were measured by washing off the sporangia and reincubating the leaves. Total sporulation was measured by summing the daily totals (Fig. 4).

Large differences in sporing rates were observed on the five varieties and these differences reflected the degree of resistance which had been observed under unsprayed conditions in the field.

SHOOT TESTS

Another method which has been used for testing resistance involved the use of pot plants. These were grown from two node cuttings (Williams and Sykes, 1959). All shoots except one were pinched out and when this shoot had reached approximately 50 cm. in length it was cut back to three nodes above soil surface. The resulting lateral shoots were atomized with a suspension of sporangia of *Pseudoperonospora humuli* (20,000 sporangia per ml.) when they were approximately 2.5 cm. long. After incubation in a cold frame for periods varying from 10-15 days the percentage of shoots which became lateral spikes was measured. The results of four tests each involving six plants of each variety are shown in Table 1.

With the exception of CC77 in test 2 the pot test reflected the apparent degree of field resistance of the varieties.

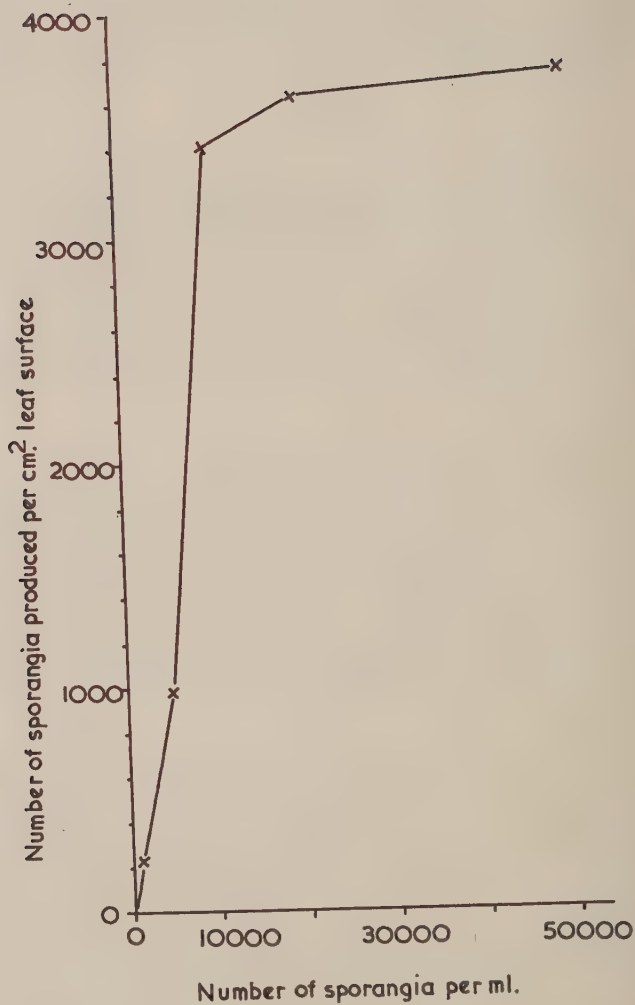


FIG. 2
The relationship between concentration of sporangia of *Pseudoperonospora humuli* and infection of detached leaves of Eastwell Golding.

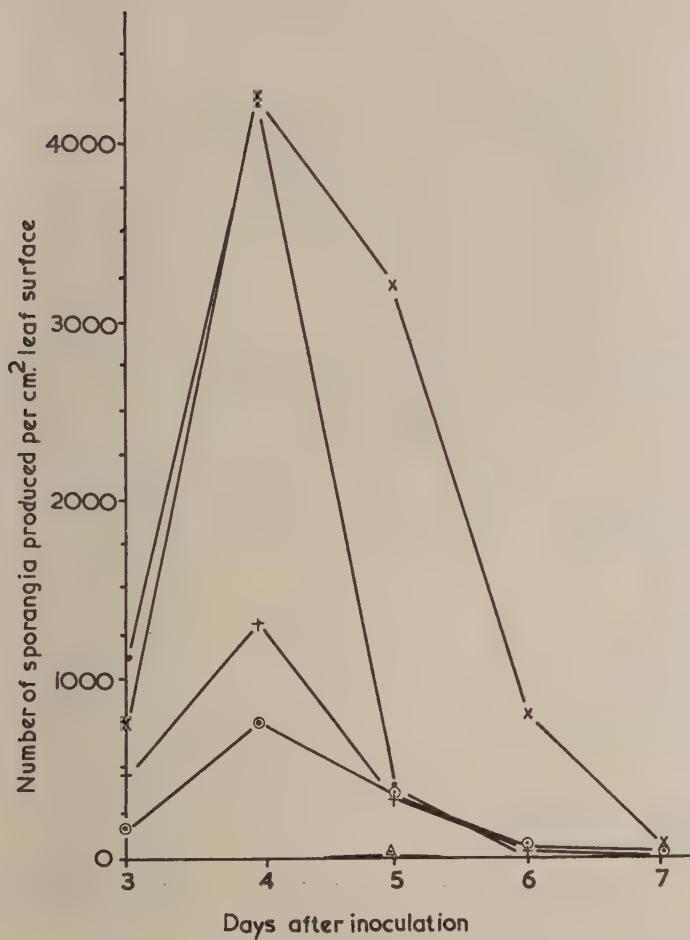


FIG. 3

Daily sporangia rates on detached leaves of five hop varieties inoculated with *Pseudoperonospora humuli*—X Eastwell • CC77, † Fuggle N, ⊙ 16/54/14, △ 2L118.

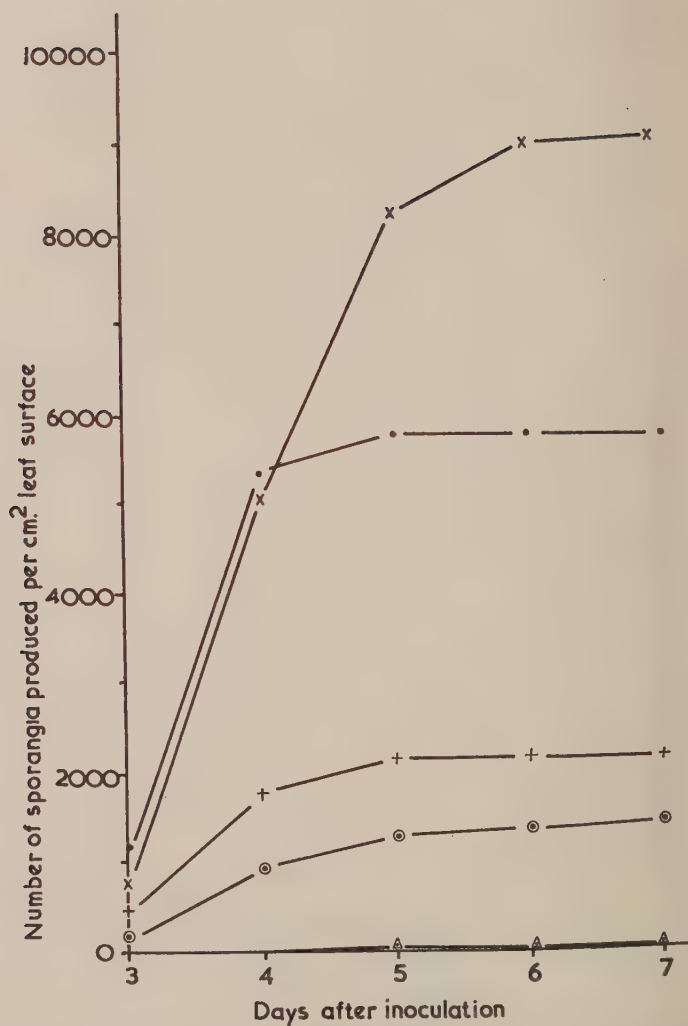


FIG. 4
Total sporang rates on detached leaves of five hop varieties inoculated with
Pseudoperonospora humuli—X Eastwell Golden, • CC77, + Fuggle N,
⊙ 16/54/14, Δ 2L118.

TABLE 1

INFECTION OF SHOOTS OF POT PLANTS OF FIVE HOP VARIETIES INOCULATED WITH
Pseudoperonospora humuli

Variety	Percentage of shoots which became lateral spikes			
	Test 1	Test 2	Test 3	Test 4
Eastwell Golding	81	73	54	80
CC77	76	30	45	75
Fuggle N	61	54	27	36
16/54/14	8	17	6	13
2L118	0	0	0	0

CONCLUSIONS

The preliminary results described in this paper suggest that both the detached leaf and shoot test methods can be used for the assessment of varietal resistance to downy mildew disease although the real efficiency of such techniques cannot be known until the performance of large numbers of seedlings screened by means of them is observed under field conditions. It is possible that factors other than inherent susceptibility are concerned in the field reaction of a variety to downy mildew disease. Likely factors such as habit of growth and time of flowering can only be observed in the field.

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HOP PROPAGATION

III. THE GROWTH OF SUITABLE MATERIAL FOR THE PROVISION OF SOFT-WOOD CUTTINGS FOR MIST PROPAGATION AND THE SUBSEQUENT BEHAVIOUR OF THE CUTTINGS IN THE FIELD

I. H. WILLIAMS and R. F. FARRAR

SUMMARY

Techniques to supply material for soft-wood cuttings at different times of the year are described. The development of the rooted cuttings when planted out in the field at intervals during the season is discussed. Soft-wood cuttings planted in the field after propagation in the mist unit compared well at the end of the growing season with bedded setts grown in the normal commercial manner.

INTRODUCTION

The previous paper in this series described a method of rooting small soft-wood cuttings under glass using a propagating bench with controlled humidity and soil warming (Williams and Sykes, 1959). The type of cutting which proved most suitable consisted of small sections of the shoot with two nodes, the basal node buried in the propagating medium. This technique was developed primarily to satisfy the demands of the research worker for large batches of comparable clonal plants in rapid succession over the greater part of the year. This method has interested commercial propagators and in the present paper two main problems are considered; first, ways in which plants can be grown at different times of the year to supply suitable material for propagation; second, the subsequent development of soft-wood cuttings after rooting when planted in the open.

1. GROWING MATERIAL FOR MIST PROPAGATION

(a) September-April

From early September to early April stock plants must be grown under heated glass. This presents some difficulty since vegetative growth ceases in late August and will do so even in good growing temperatures in the glasshouse. The cessation of shoot growth is followed by the die-back of the shoot to soil level.

This process has been shown to be primarily a day-length response (Williams and Weston, 1959). Under a day-length of about 13 hours or less growth ceases, whereas growth can be maintained in day-lengths above this figure. Derbyshire and Dixon (1957) found that artificial light could be used to extend the day-length above the critical level and to maintain the shoot in an actively growing state. A day-length of 16 hours, using 500 watt high pressure mercury vapour lamps is recommended and a minimum temperature of 45° F. is necessary for healthy growth. Under these conditions, successive batches of cuttings rooted in the mist propagation unit can be potted off and grown on to supply further material for the two-node type of cutting. It is unlikely that the method described would be of use to the commercial propagator during this period.

(b) *February-April*

From February onwards, a supply of cuttings can be obtained from plants brought into a heated glasshouse from the field. These will be supplemented by plants grown under cold glass in March. Experiments have shown that the low temperature requirement to break the dormancy of the hop is usually satisfied by about mid-January and plants which have overwintered in the open will readily grow if brought into a heated glasshouse from this time. Plants overwintered in pots from the previous year's cuttings, strap cuts and bedded setts, all will grow away strongly and supply cutting material up to late April.

(c) *April-June*

From April to early June basal shoots from field material are generally available and can be used for propagation and the shoots root readily in a mist unit particularly if a portion of etiolated stem is included and if a few leaves towards the apex of the shoot are reasonably mature—i.e. green and expanding. A method described by Wilkinson (1954) could be adapted to supply cuttings for mist propagation. This method consists of covering the crown of the plant with 3 inches (7.5 cm.) of sand and removing the shoots when they are approximately 3 feet (90 cm.) long. By Wilkinson's method each shoot is cut back so that the cutting consists of two pairs of basal leaves and a blanched basal portion of stem. A mature crown would supply 50 or more cuttings of this type, but if these were cut up into the two-node type of cutting which root readily in a mist propagation unit they would provide a considerably larger number.

(d) *June-September*

Propagation from June to September presents few difficulties. During this period vegetative laterals from the lower parts of mature bines in the field can provide large quantities of two-node cuttings. Alternatively, pot-grown plants can be used throughout.

The data in Table 1 are based upon actual propagation carried out in the past eighteen months and indicates the type of material available at different seasons of the year.

TABLE 1
GROWING MATERIAL FOR PROPAGATION

Time of year	Type of material	Environment for growing	Type of cutting under mist
(a) Sept.-April ..	Pot grown plants from soft-wood cuttings	Heated glass-house and extended day-length	Two-node
(b) Feb.-April ..	Strap cuts or bedded setts or pot-roots overwintered in the open. Pot grown plants	Heated glass-house	Two-node or small shoots
March-April ..	As above	Cold glass	As above
(c) April-June ..	Small shoots from mature hills Pot grown plants	Field Cold glass	Two-node or small shoots
(d) June-Sept. ..	Lateral shoots from mature hills Pot grown plants	Field Cold glass	Two-node cuttings

2. GROWING ON SOFT-WOOD CUTTINGS IN THE OPEN

Although plants can be grown from soft-wood cuttings throughout the year, the period when these are likely to survive if planted out in the field is limited to the six months from April to September. A further limitation from the viewpoint of the commercial propagator is that a sufficient growing period must be allowed for the rootstock to develop to a size comparable with a bedded sett before Autumn brings an end to the growing season.

In 1959 it was decided to supplement clonal material used

in the Wye/East Malling Joint Scheme with some material propagated from soft-wood cuttings. Two varieties were used, W/E1008 and W/E1778. This offered an opportunity to examine the size of rootstock developed at the end of the growing season by successive batches of rooted soft-wood cuttings planted out during the growing season, from late April to the end of July. The source material consisted of a few small plants which had been overwintered in an unheated glasshouse in pots. These began growing at the beginning of March and the first cuttings were taken from the new growth about three weeks later. The method of rooting under mist has been fully described in the previous paper (Williams and Sykes, 1959). After becoming established, plants were potted-off into good compost in 3½ inch whalehide pots* and early batches were hardened off in cold frames for about ten days prior to planting in the field.

Plants were planted out in the field in their whalehide pots 12 inches (30 cm.) apart in nursery rows. Where possible a dull day or a day following rain was selected for this operation, but the season of 1959 was exceptionally dry and two batches were given approximately one gallon of water per pot immediately after planting. Otherwise no irrigation was given. The plants were trained up strings 6 feet (1·8 metres) high.

RESULTS—TABLE 2

Early batches made good growth and even produced a few cones; later batches, as might be expected, made less growth and this was particularly marked in batches planted out on 2nd July and later. In column 4 an assessment of vegetative growth based upon the mean height of bines in each batch is given. Laterals from the earlier batches could have provided further material for propagation had this been required.

In February, 1960, all the plants were lifted and weighed. They were compared with the weight of 10 setts of each of the same two varieties grown on from layered cuts in the nursery in the conventional manner. These data are shown in column 5. *The cuttings planted out in April, May and June were as well developed at the end of the season as the bedded setts obtained by the normal commercial method.* Batches planted in July made smaller rootstocks at the end of the season and although quite strong, would probably require

* This type of pot is expendable and roots appear to have no difficulty in penetrating the sides and bottom so that the practice has been to plant the entire pot in the soil when planting out.

TABLE 2
BEHAVIOUR OF SOFT-WOOD CUTTINGS (AFTER ROOTING)
PLANTED IN THE FIELD

Date planted in the field	Variety	No. of plants*	Mean height of shoots on 23.7.59 cm.	Mean weight of Setts on 22.2.60 gm.
28.4.59	W/E 1008	48	178.8	212.5
11.5.59	W/E 1008	55†	223.1	250.1
	W/E 1778	11†	184.6	265.0
2.6.59	W/E 1008	58	125.8	266.0
	W/E 1778	7	111.0	263.0
23.6.59	W/E 1008	5	62.6	230.0
	W/E 1778	33	67.0	218.0
2.7.59	W/E 1778	7	47.0	142.0
10.7.59	W/E 1778	60	23.6	111.0
28.7.59	W/E 1778	47	not recorded	135.0
	W/E 1008	Ten bedded setts from layer cuts taken in 1958		223.0
	W/E 1778	"		177.0

* Number of plants based on requirement and not on the total number of cuttings available.

† Watered in.

more care in the initial stages, if planted in a commercial garden.

DISCUSSION AND CONCLUSIONS

The method of growing material to supply soft-wood cuttings will depend upon the time of year and forms and quantity of the initial stock available. Where only a few plants are available in the form of bedded setts or strap cuts it would probably be worthwhile to rely upon pot-grown material throughout the year. A glasshouse heated during the winter period and incorporating artificial illumination will be required. Conversely, if mature hills of the variety already exist, large quantities of material suitable for propagation are available during the growing season.

The actual propagation is not difficult if reasonable care is taken in preparation of the cuttings and since the mist unit is largely automatic, labour costs are minimized. The techniques described lie within the scope of a competent horticulturist. The two-node type of cutting roots very readily in two weeks or less and is the most effective type where rapid clonal build-up is required.

Alternatively small entire shoots will root readily at the time of the year when these are available.

After establishment, plants potted off into whalehide pots require attention to watering and gradual hardening off for about ten days before planting in the field. This may involve the use of a few cold frames. From the preliminary experiment described, rooted cuttings planted in the field from April to July provided the size of plant at the end of one season comparable with the conventional bedded sett. With the latter, two years are needed to reach this stage since one season's growth is needed to produce the strap or layer cut which must then be grown on for a second season to develop into the sett (Farrar, 1958). Thus a considerable saving in time is possible.

Although we now know that a very wide variety of hops can be propagated in this manner, a more detailed experiment is in progress to assess further the behaviour of soft-wood cuttings planted in the field.

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HEIGHT OF WIREWORK AND SPACING TRIAL NO. II: FIRST PROGRESS REPORT

PART I. INTRODUCTION

F. C. THOMPSON

IN growing hops for the picking machine it is generally considered that the type of growth to aim at is a strong bine, with the cone-bearing laterals distributed evenly along it and without a large tangled head.

The grower can influence in a number of ways, the type of growth produced by a hop plant. When planting a new garden or rewiring an old one, three important decisions to make are the width of planting to be chosen, the height of wirework to be adopted, and the variety or varieties to be grown.

These factors were investigated in a trial at Wye from which data were obtained for the three years 1953-55 (Thompson, 1957). Unfortunately, the trial then had to be grubbed owing to an outbreak of progressive *Verticillium* wilt in the garden concerned. Over this limited period, however, the results showed that both wider spacing and higher wirework encouraged the type of growth considered to be best suited to the machine, but wider planting markedly reduced yield per acre whereas higher wirework tended to increase yield, particularly with more vigorous varieties.

A weakness of this first trial, however, was that although designed to study factors in relation to machine picking, the plots were, in fact, picked by hand. This difficulty was removed by the purchase of a picking machine by the College in 1958. In the same year a second trial was planted in the new Withersdane hop garden on a site on which no hops had been grown in living memory. The soil in this garden is a brickearth overlying chalk downwash material (coombe deposit).

EXPERIMENTAL

Three heights of wireworks were used, namely 14 ft., 16 ft. and 18 ft. (4.1, 4.7 and 5.3 metres). These were greater by one foot (30 cm.) in each case than the corresponding heights tested in the previous trial; it was considered that 14 ft. (4.1 metres) was the

minimum height likely to be adopted for new wirework in commercial practice. Umbrella stringing of the normal open type was employed in all treatments giving four strings per plant.

The hops were planted at three different spacings in one direction of $6\frac{1}{2}$ ft., $7\frac{1}{2}$ ft. and 9 ft. (2.0, 2.3 and 2.7 metres). The cross spacing was uniform at $6\frac{1}{2}$ ft. (2 metres) to facilitate cross cultivation. Considered as a square plant the spacing treatments were approximately $6\frac{1}{2}$ ft., 7 ft. and $7\frac{1}{2}$ ft. (2.0, 2.3 and 2.6 metres) square respectively. The only change from the previous trial was that the smallest spacing was increased from 6 ft. (1.8 metres) to $6\frac{1}{2}$ ft. (2.0 metres) in conformity with current commercial practice.

Three varieties were tested: Fuggle N, Northern Brewer and Bullion. Of these Fuggle N is a native English hop representative of two-thirds of the total commercial acreage in the country. It is an early mid-season variety of moderate vigour which bears its crop as soft and relatively light cones on long laterals. It is not regarded by growers as a good variety for machine picking.

Northern Brewer and Bullion are commercially accepted Wye Varieties, bred by the late Professor Salmon from American as well as English parentage. Both have firm dense cones of high resin content and both are regarded as better varieties for the picking machine than Fuggle. Northern Brewer is a mid-season variety of moderate vigour with short laterals. Bullion is a high yielding late variety which is vigorous in growth and has long laterals.

The previous trial comprised four varieties: Fuggle N, John Ford, Bullion and Brewer's Gold. Brewer's Gold was eliminated in the present trial since its habit of growth closely resembles that of the more commercially acceptable Bullion. John Ford was replaced by its sister seedling Northern Brewer, a variety of similar growth habit but of much greater commercial popularity.

The experimental design adopted was that used in the earlier trial, the height treatments being tested on relatively large plots of approximately $\frac{1}{4}$ th acre (0.07 hectares), in duplicate and the spacing treatments randomized in three sub-plots of 36 hills within each whole plot.

REFERENCE

- THOMPSON, F. C. (1957). The effect of spacing and height of wirework on the pattern of growth, yield and resin production of hops. *J. Inst. Brew.*, **54**, 399.

PART 2. CULTURAL DATA INCLUDING YIELD AND RESIN VALUES

F. C. THOMPSON

GENERAL

The plants were sufficiently well established for crop yield data to be taken in 1959, when in addition to recording the main treatment effects it was decided to use the trial to investigate the efficiency of machine picking for the harvesting of experimental plots. Each sub-plot was divided into two 18-hill half plots, one to be picked by machine and the other by hand, in order to get a comparison between the yield of clean, dry hops picked by the two methods.

In the end, only Fuggle N and Bullion were so harvested, as owing to an attack of powdery mildew Northern Brewer had to be picked by hand, before the experimental recording staff were available. Northern Brewer was, however, picked in half-plots, so providing data on variability within the sub-plots. The results obtained from the investigation of hand and machine picking are discussed on page 60 below.

CROP YIELD

The results obtained, in terms of yield per plant and yield per acre, are summarized in Tables 1 and 2 respectively.

Only the main treatment effects are considered, the data being expressed in terms of the means of the sub-plot yields, which in the case of Fuggle and Bullion represent the bulked yields from the hand and machine picked half plots.

YIELD PER PLANT

The results obtained show that there has been a rise in yield per hill with increase in width of plant, the effect being most pronounced with the strong-growing Bullion, as might be expected. The small yield increase found with Northern Brewer is surprising, however, as this variety was picked under-ripe and the wider spacings might have been expected to encourage earlier ripening and so have accentuated the yield differences between the spacing treatments.

Higher wirework has given a progressive increase in yield

TABLE 1
EFFECT OF HEIGHT AND SPACING ON YIELD PER PLANT
(MEAN VALUES EXPRESSED AS LB. DRY HOPS*)

Variety	Height	Spacing ($\times 6\frac{1}{2}$ ft.)			Mean
		$6\frac{1}{2}$ ft.	$7\frac{1}{2}$ ft.	9 ft.	
Fuggle N	14 ft.	2.24	2.31	2.40	2.32
	16 ft.	2.29	3.53	2.64	2.49
	18 ft.	2.28	2.41	2.61	2.43
	Mean	2.27	2.42	2.55	2.41
Northern Brewer ..	14 ft.	2.60	2.66	2.73	2.66
	16 ft.	2.57	2.83	2.78	2.73
	18 ft.	2.68	2.57	2.60	2.62
	Mean	2.62	2.68	2.70	2.67
Bullion	14 ft.	2.73	2.73	3.07	2.84
	16 ft.	2.72	3.13	3.25	3.03
	18 ft.	3.04	3.13	3.32	3.16
	Mean	2.83	3.00	3.21	3.01

* Yields of Fuggle and Bullion in terms of clean, oven-dry hops; Northern Brewer in terms of kiln-dry hops as picked.

TABLE 2
EFFECT OF HEIGHT AND SPACING ON YIELD PER ACRE
(MEAN VALUES EXPRESSED AS CWT. DRY HOPS*)

Variety	Height	Spacing ($\times 6\frac{1}{2}$ ft.)			Mean
		$6\frac{1}{2}$ ft.	$7\frac{1}{2}$ ft.	9 ft.	
Fuggle N	14 ft.	20.58	18.38	15.93	18.29
	16 ft.	21.10	20.57	17.56	19.74
	18 ft.	20.97	19.18	17.36	19.17
	Mean	20.88	19.37	16.95	19.07
Northern Brewer ..	14 ft.	23.95	21.16	18.15	21.09
	16 ft.	23.58	22.54	18.49	21.53
	18 ft.	24.64	20.52	17.28	20.81
	Mean	24.06	21.40	17.97	21.14
Bullion	14 ft.	25.13	21.77	20.39	22.43
	16 ft.	25.06	24.94	21.65	23.88
	18 ft.	27.98	24.98	22.07	25.01
	Mean	26.06	23.89	21.36	23.77

* Yields of Fuggle and Bullion in terms of clean, oven-dry hops; Northern Brewer in terms of kiln-dry hops as picked.

with Bullion, but both Fuggle and Northern Brewer have cropped best at 16 ft., the yield falling-off at 18 ft.

When the interaction between height and spacing is considered, it may be seen that both Fuggle and Bullion have shown a greater

benefit from higher wirework at the wider spacings. With Northern Brewer, however, there are no consistent interaction effects.

YIELD PER ACRE

It is clear from Table 2 that with wider spacing the increase in yield per plant obtained does not compensate for the resultant smaller number of plants per acre. Even with the strong growing Bullion, there is a marked drop in yield per acre, although the percentage fall in yield is less than with the other varieties.

The influence of height of wirework directly reflects the effect of this treatment on yield per plant, so comparable results are found. With Bullion, the rise in yield obtained to some extent compensates for the loss found with the increase in spacing from $6\frac{1}{2} \times 6\frac{1}{2}$ ft. to $6\frac{1}{2} \times 7\frac{1}{2}$ ft.

RESIN CONTENT: PER CENT. RESINS IN CONES

A summary of the results obtained is given in Table 3, and it may be seen that there were no consistent treatment effects with any of the three varieties.

TABLE 3

EFFECT OF HEIGHT AND SPACING ON RESINS CONTENT OF HOPS. MEAN VALUES FOR TOTAL SOFT RESINS (T.S.R.), ALPHA ACIDS AND BETA FRACTION, EXPRESSED AS PERCENTAGE DRY HOPS

	Height			Spacing ($\times 6\frac{1}{2}$ ft.)		
	14 ft.	16 ft.	18 ft.	$6\frac{1}{2}$ ft.	$7\frac{1}{2}$ ft.	9 ft.
Fuggle N						
T.S.R.	8.67	8.29	8.92	8.88	8.52	8.48
α -acids	4.61	4.45	4.69	4.71	4.53	4.52
β fraction	4.06	3.84	4.23	4.17	3.99	3.96
Northern Brewer						
T.S.R.	9.87	10.21	10.37	10.39	9.84	10.23
α -acids	5.74	5.95	6.10	6.06	5.70	6.02
β fraction	4.13	4.26	4.27	4.33	4.14	4.21
Bullion						
T.S.R.	14.48	14.22	14.48	14.01	14.65	14.53
α -acids	8.10	7.80	7.98	7.81	8.23	7.87
β fraction	6.38	6.42	6.50	6.20	6.42	6.66

The less dense growth found with wider spacing and higher wirework, should allow more light to fall on the developing cones, and it might be expected that this would favour an increase in

resin content. This is not borne out by the results obtained, however, but 1959 was an exceptional summer when the total hours of sunshine was well above average. Under these conditions it may well be that the light intensity is such that differences in light accessibility, due to different growth patterns, are of little or no importance.

This possibility is supported by the results of the earlier trial (Thompson, 1957) where in the dull summer of 1954, consistent increases in resin content were found with wider spacing and higher wirework, whereas in the sunnier summer of 1955 the results were contradictory.

REFERENCE

- THOMPSON, F. C. (1957). The effect of spacing and height of wirework on the pattern of growth, yield and resin production of hops. *J. Inst. Brew.*, **54**, 399.

PART 3. COMPARISON OF HALF PLOTS PICKED BY HAND AND MACHINE

P. H. BAILEY

VARIOUS difficulties must be resolved before experiments can confidently be picked by machine in any season. In an investigation of paired pocket samples from similar growths hand- and machine-picked in the 1954, 1955 and 1956 crops, Darling and Thompson (1956, 1957) found that with machine picking there was a tendency to increased damage and increased inclusion of leaf and stem, and a definite reduction of resin content which could not be entirely accounted for by the increased dilution with leaf and stem. Results obtained from experiments by machine picking would, therefore, not be directly comparable with results obtained by hand picking. General experience with separating mechanisms in agricultural use suggested that it would be impossible to arrive at a simple correction factor to convert results obtained by one picking method into terms of the other, and that straightforward use of a machine would introduce a subjective element into the results obtained because of the wide range of control exercised by the operator.

Modern field experiments are laid out as a series of randomized small plots so that results can be examined statistically and distinctions made between significant treatment differences and differences due to non-experimental variability in plants and soil and in the techniques used. In this context the use of picking machines for hop experiments raises two problems. First, mechanical picking may so increase extraneous variability as to reduce the probability of demonstrating significant treatment differences. Second, the conventional commercial-type hop-picking machines available are intended for harvesting large areas continuously and are not designed for harvesting separately large numbers of small plots.

In harvesting hop plots with a conventional machine, two approaches appear to be possible: either to feed bines to the machine continuously, estimating yield by determining the output-rate of picked hops in relation to the rate of feeding bines during the picking of any plot, or else to run the machine empty between plots. These two possibilities were investigated in an observation trial during the harvest of 1958, when guard row

plants in an experiment on insecticides were harvested by the newly-installed Rotobank 275 machine at Wye College, the experimental plots themselves being picked by hand. The results suggested that the technique of running the machine empty between plots was preferable. With 18-hill (72 string) plots there was no noticeable difference in the performance of the machine when starting up and when running empty from that when running steadily with an intake of approximately 6 strings per minute. It may be noted that this rate is at the lower end of the commercial intake range suggested by the manufacturers, i.e. 6-12 strings per minute.

The general results of this observation trial confirmed the expectation of greater damage and higher leaf and stem content with machine picking, but the results obtained for yield were comparable with those from hand picking and moreover placed the three insecticidal treatments in the same order of merit. This was considered sufficiently encouraging to proceed with the more elaborate comparison of hand and machine picking of experimental plots in 1959 which is discussed below.

The 1959 comparison was made on the new height of wirework and spacing trial at Wye College; details of this trial are given on page 54 above. Its standard units are randomized sub-plots of 36 hills which for the purpose of this comparison were divided into half plots of 18 hills (72 strings) each. Half of each sub-plot was picked by hand on the same day as the other half was picked by machine. Yields of half plots were recorded separately and in all 36 pairs of half plots were so harvested. The allocation of half plots for hand and machine picking was not randomized.

EXPERIMENTAL

The 72 strings from each half plot were brought to the machine as two trailer loads. They were put on alternate clamps on the bine track, which was run at about three-quarters of its maximum speed, giving an intake rate of approximately 6 strings per minute, and the machine was run empty at the conclusion of each half plot and after picking guard row material as in 1958. On the first day of the experiment six half plots were picked in addition to guard row material from machine-picked and hand-picked plots. Later, the number of actual half plots picked per day was reduced to four, two in the morning and two in the afternoon, so that hand picking and machine picking of comparable half plots could be carried out at about the same time.

The machine was set so that a minimum of useful hop material was rejected, and consequently tended to include rather more leaf and stem in the sample than would have been obtained if more hops had been rejected. Spot checks indicated that with such a setting the weight of good hop material rejected was negligible. Settings were left constant during the picking of each plot, and as far as possible constant through the whole experiment. All the green hop material was sampled, so that the dry matter content, resin content, degree of contamination by leaf and stem, and the degree of damage of the hand-picked as well as the machine-picked samples could be determined. For dry matter content and sorting, three samples per half plot, weighing 200-300 gm. each, were taken from the machine, the sampling tray being traversed across the end of the inspection table on six occasions during the picking of the plot. In addition, one sample of about 500 gm. was taken from each half plot for resin determination.

The smaller samples were weighed to 0.5 gm. with the minimum of delay, and were then sorted manually into the following fractions while still green:

Whole hop	}	= Total hop
Broken hop		
Petal and detritus		
(excluding recognizable small pieces of leaf)		
Leaf	}	= Total impurities
Stem		
Foreign matter		

Sorting was usually carried out within an hour or two of picking, to minimize errors from respiration losses; in one or two instances samples were kept overnight in a refrigerator. After sorting, the individual fractions were dried in an oven for 4 hours at 105° C., and weighed dry. The proportions of the dry components were thus obtained, and from the ratio of the sum of the total dry material to the original total green weight, the dry matter content. The ratio of the dry material to the original green sample weight was available to convert the half plot yields, weighed as green material, into terms of "clean dry hops".

RESULTS

As the division of the sub-plots into half plots was not randomized, numerical comparison of results from the two picking methods is not strictly valid. In practice, gross differences shown between picking methods, for instance in petal content of the samples, are almost certainly genuine, but small differences may be due to some factor such as variation of soil fertility if it is linked with geographical position. The fact that both sets of half plots of Northern Brewer were hand-picked has provided a check on this point, as shown in Table 1.

TABLE 1
OVERALL MEAN YIELDS PER PLANT, EXPRESSED AS LB. DRY HOPS*

Variety	Fuggle N		Northern Brewer		Bullion	
Half plot position ..	A	B	A	B	A	B
Picking method ..	H	M	H	H	M	H
Yield ..	2.35	2.48	2.73	2.60	3.04	2.99

* Fuggle and Bullion yield in clean oven-dry hops per plant; Northern Brewer in kiln-dry hops per plant as picked.

The differences in Fuggle and in Northern Brewer are significant. It follows that the small mean differences in Fuggle and Bullion, which might have been attributed to picking method, are at least equally likely to have arisen from other factors connected with the geographical positions of the half-plots.

The effect of spacing and height as demonstrated by the results from hand picking and machine picking for weights of clean dry hops per plant is shown graphically in Fig. 1. The general trends are similar, and correspond with those previously shown by Thompson (1957). There are no significant effects for height. The machine-picked data indicate a highly significant trend to increased yield per plant with wider spacing for Fuggle, which is not shown for the hand-picked data; on the other hand, the significant trend to increased yield per plant with wider spacing for Bullion shown by the machine-picked data is shown as a highly significant trend by the hand-picked data.

COMPOSITION OF SAMPLES

No significant effects of height or spacing on total soft resins or alpha resin are shown by machine-picked or hand-picked data. Table 2 shows the overall mean values obtained.

TABLE 2
MEAN RESIN CONTENTS, PERCENTAGE CLEAN DRY HOPS

Variety	Fuggle N		Northern Brewer		Bullion	
	A	B	A	B	A	B
Half plot position ..	H	M	H	H	M	H
Picking method ..	8.70	8.56	10.30	10.00	14.16	14.63
Total soft resins ..	4.69	4.48	5.93	5.92	7.93	8.00
Alpha acids ..						

There appears to be a consistent trend towards lower resin content in the machine-picked samples but in view of the difference shown in the half plot values for total soft resins in hand-picked Northern Brewer, this cannot be confirmed.

Table 3 shows the mean proportions of the various physical fractions of the hops, expressed as percentages. The proportion of foreign matter was negligible, and is omitted from the table.

TABLE 3
MEAN PHYSICAL COMPOSITION OF SAMPLES

Variety	Fuggle N		Bullion	
	Machine	Hand	Machine	Hand
Picking Method				
D.M. content of green hops, percentage ..	23.7	24.1	29.6	29.1
Whole hops % of d.m. ..	60.9	76.9	58.7	77.8
Broken hops % of d.m. ..	22.1	14.8	32.1	18.2
Petal % of d.m. ..	9.9	4.6	4.6	1.2
Total hop (purity) % of d.m. ..	92.9	96.3	95.4	97.2
Leaf % of d.m. ..	5.36	3.27	3.61	2.21
Stem % of d.m. ..	1.76	0.43	1.01	0.60
Total impurities % of d.m. ..	7.12	3.70	4.62	2.81

Clearly the tendency for machine picking to produce a more broken sample with higher leaf and stem content found by Darling and Thompson (1956, 1957) is reflected in these results, but all the differences are more marked. The petal fractions are much lower in the present results, implying that in the earlier work breakage in drying and pressing tended to obscure the differences. The proportion of broken hops was apparently higher in the Bullion than in the Fuggle, although the petal fraction was higher in the Fuggle. There is evidence in the detailed data that the division between whole and broken hop was subjective, and that this result only reflects a more critical standard of manual sorting in the

second week of the experiment when the Bullion was being picked; it is proposed to omit this division in future work, as the petal fraction appears to be a satisfactory index of damage provided the picking machine is set so as not to reject an undue proportion of petal.

No significant effects of height or of spacing on the dry matter content or on any of the fractions were found, but a tendency for increased height to produce less shatter was noted in the petal results which approached significance for both machine-picked and hand-picked Fuggle, the mean results being shown in Table 4.

TABLE 4
EFFECT OF HEIGHT ON PETAL CONTENT,
PERCENTAGE OF DRY MATTER

Variety					Fuggle N		Bullion	
Picking Method					Machine	Hand	Machine	Hand
Height	18 ft.	..	..	..	7.63	3.40	4.30	1.19
	16 ft.	..	..	..	10.45	4.77	4.28	1.14
	14 ft.	..	..	..	11.64	5.55	5.09	1.18

COEFFICIENTS OF VARIATION

It is impossible to comment adequately on the suitability of the picking machine for harvesting experimental plots without making a numerical comparison of the variability of the data collected from the half plots by the two methods. This is done in Table 5 which shows the coefficients of variation for the two methods, based on the combined error variance.

In general the coefficients of variation are if anything lower for

TABLE 5
COEFFICIENTS OF VARIATION

Variety					Fuggle N		Bullion	
Picking method					Machine	Hand	Machine	Hand
Yield per plant					0.069	0.070	0.069	0.039
Petal content					0.194	0.249	0.180	0.175
Total soft resin					0.104	1.137	0.088	0.098
Alpha acids					0.104	0.141	0.073	0.081

machine picking than for hand picking, though the coefficient for the yield per plant of clean, dry, hand-picked Bullion is exceptionally good. Checking shows that the coefficient reflects consistent data throughout this combination of variety and picking method: it is the low variability of the data that is largely responsible for the high significance of the trend noted in Fig. 1 for this variety to give higher yield per plant with wider spacing.

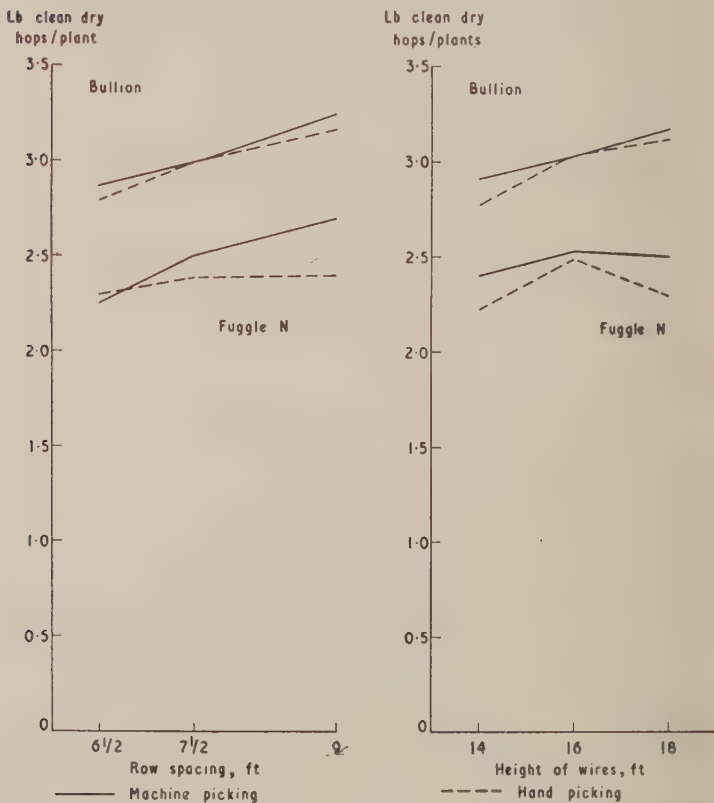


FIG. 1.
Yield of clean dry hops per plant: results for hand and machine picking plotted separately.

CONCLUSIONS

To sum up, it appears clear within the limits of the non-randomized layout of the half plots, that in the consistent hot dry weather of the 1959 harvest in Kent the use of the picking machine gave very similar mean results to hand picking, and did not add to variability. It will be necessary to continue the comparison of harvesting methods to include various weather and crop conditions, and to extend it to the harvesting of other experiments, before making a full report.

REFERENCES

- DARLING, H. S. and THOMPSON, F. C. (1956). The effect of machine picking on the resin content of hops. *Rep. Dep. Hop Res. Wye Coll. for 1955*, 104.
- and ——— (1957). The effect of machine picking on the resin content of hops—1956 crop. *Ibid for 1956*, 44.

PART 4. A NOTE ON GROWTH AND DEVELOPMENT

I. H. WILLIAMS

THE height of wirework and spacing experiment offers an opportunity to study the growth and development of the hop under different cultural conditions. In 1959, during harvesting, a growth analysis was carried out on 16 bines from two hills in each treatment. The number of cones and their distribution up the bines were recorded for the varieties Fuggle and Bullion. Sampling was insufficient to justify statistical analysis, and was aimed primarily at providing initial data to be extended in 1960 when the plants will be reaching maturity. It is also likely that the exceptionally dry season of 1959 affected the growth of these young plants and may have modified treatment effects in a manner not likely to occur in years with more normal rainfall distribution and with mature hills.

RESULTS

These are summarized in Table 1.

TABLE 1
HEIGHT OF WIREWORK GROWTH ANALYSIS
(ALL MEANS OF 16 BINES/TREATMENT)

Variety	Height and Spacing Treatment Feet	Mean Ht. of Bines cm.	Ht. to* 1st cones cm.	No. cones below top wire	No. cones above top wire	Total No. cones
Fuggle	14 × 6½	580	239	798	513	1,311
	14 × 9	594	152	842	590	1,432
	18 × 6½	655	263	1,303	140	1,443
	18 × 9	669	179	976	294	1,270
Bullion	14 × 6½	616	233	639	305	944
	14 × 9	716	170	712	338	1,050
	18 × 6½	770	241	1,475	132	1,507
	18 × 9	682	166	1,997	169	2,166

* At least 3 cones on a lateral.

HEIGHT OF BINES

The mean height of bines is shown in Table 1. Those on the higher wirework tended to be longer, but this was due mainly

to the fact that on the lower wirework at 14 ft. many of the bines had lost their terminal portions during the growing season.

LENGTH OF BINE TO FIRST CONES

Examination of mature hops in the past few years has shown that the number of cones developing on laterals varies with the position of laterals on the bine. Basal laterals tend to be more vegetative. In the present experiment the closely planted treatments had fewer cones on the lower laterals, and the first laterals to bear cones as well as leaves occurred higher up the bine. This was a particularly interesting finding and suggests that possibly light may be important in the proper development of cones on the lower laterals, mutual shading being greater in the closer plantings.

DISTRIBUTION OF CONES ON THE BINE

With Bullion, the heavier yields per plant found with both higher wirework and wider spacing are associated with an increase in the total number of cones, though this increase is much larger with higher wirework. With Fuggle a similar trend is found for three of the four treatments recorded, but with 18 ft. wirework and 9 ft. spacing the trend is reversed. This anomalous result is probably due to a sampling error because of the limited number of hills it was possible to examine. The number of cones on the 14 ft. wirework above the top wire was larger with both varieties, and was associated with the development of a dense "head". On the higher 18 ft. wirework very little head developed, the majority of cones being below the top wires on laterals well spaced up the bine. This is thought to be of importance in machine picking.

CONCLUSIONS

As a prelude to more detailed studies in 1960, the observations made in 1959 suggest that wider spacing results in the development of cones on laterals lower down the bine. Increasing the height of wirework does result in a more even distribution of cones along the bine as a whole, with an absence of the "heads" found on low wirework. There is some evidence that the increase in yield found with higher wirework and wider spacing is associated with an increase in the total number of cones per bine.

HOP IRRIGATION—PROGRESS REPORT

I. H. WILLIAMS and J. F. BROWN*

SUMMARY

The irrigation experiment in progress at Bodiam, Sussex, is described and the results for 1958 and 1959 discussed; increase in yield was obtained with irrigation in 1959. Other work at Guinness Hop Farms Ltd. on the commercial irrigation of the hop is evaluated.

INTRODUCTION

The problems and techniques involved in assessing the irrigation needs of a crop plant were outlined in a previous paper (Williams, 1958). The application of this to the irrigation of the hop was also discussed. At the request of Guinness Hop Farms Ltd. an experiment was planned for 1958 and subsequent years to obtain experimental evidence of the effect of irrigation upon hop yields. This experiment was designed by this Department, and its operation, choice of site and analysis of results is being carried out by Guinness Hop Farms Ltd., at Bodiam, Sussex. Owing to the variability of rainfall in this country from year to year an irrigation experiment requires three or more growing seasons before any firm conclusions can be drawn. The present paper is, therefore, in the nature of a progress report with the object of assisting growers who are considering irrigation (or who have already purchased equipment) to understand the problems involved. With this in view some data from the general commercial irrigation practice at Bodiam is also given in Part II.

PART I. IRRIGATION TRIALS AT BODIAM, 1958, 1959

MATERIALS AND METHOD

Site and Soil

The site offered was approximately 12 acres of a garden called Baybrook. The ground was reasonably level, consisting of a terrace 15 ft.-20 ft. above the River Rother. This garden had been tile-drained in 1952 and the level of the water table was read throughout

* Guinness Hop Farms Ltd., Park Royal Brewery, London, N.W.10.

the growing season in 1959 from a series of bore holes dug across the site.

The soil is classified as the Shaw series, a heavy alluvium overlying Wadhurst Clay derived from drift material from the River Rother. The soil showed signs of earlier impeded drainage.

Soil moisture characteristics were established for the site using the sunflower technique of Veihmeyer and Hendrickson (1949). This gave a field capacity of about 25 per cent. water and a permanent wilting point at 9.9 per cent. On this basis a permissible deficit of 1.1.5 inches was agreed, in consultation with J. North, N.A.A.S., West Midland Region, who was planning a similar irrigation experiment with hops in the West Midlands.

The Plant and Cultivation

The crop consisted of 8.9 year old hills of the variety Fuggle N at a standard commercial spacing of $6\frac{1}{2} \times 6\frac{1}{2}$ feet, approximately 1031 hills to the acre, with parallel wirework at 14 feet. Stringing was on the umbrella system, with ten bines per hill. Dressing, training, manuring and pest and disease control were as for normal commercial practice in both years.

Irrigation

Irrigation requirements were assessed using the method developed by Penman (1953, 1954) based upon current meteorological data obtained at Bodiam. When the permissible deficit as calculated was reached, a measured quantity of water was given to bring the soil back to field capacity.

Water was applied using Wright Rain sprinklers at 40 ft. $\times$ 50 ft. centres in 1958 modified to 40 ft. $\times$ 40 ft. centres in 1959. Prior to the experiment this system of irrigation had been examined for uniformity of distribution, wind drift and rate of application and was considered satisfactory in these respects.

Four treatments were given. These were designed to show the overall effect of irrigation and to give some evidence of the periods of the growing season at which this was most likely to be effective. Treatments consisted of:

- (1) Irrigation from end of April to late August.
- (2) Irrigation from end of April to mid-June.
- (3) Irrigation from mid-June to late August.
- (4) Control—no irrigation.

Plots consisted of about 1,100 hills and each treatment was replicated twice.

RESULTS

Irrigation, 1958

The 1958 growing season was exceptionally wet. In Tables 1 and 2 the data for the irrigation experiment are given. Rainfall was high throughout the growing season and only 2.25 inches of irrigation were applied to the wettest treatment so that it is not surprising that no significant differences between treatments were obtained attributable to irrigation. Attention is drawn to the yield figures in which variation, probably due to inherent differences in soil fertility, were shown. The yield differences were larger than any obtained from the treatments in 1959 when conditions were presumably optimal for irrigation (see Table 4 below). In view of this and the high water table it was hoped to find a different site in 1959, but this proved impossible. These data are considered below in the "Discussion and Conclusion".

TABLE 1
IRRIGATION, 1958

Month	Rainfall in inches*	Treatments Irrigation applied (inches of water)*		
		1	2	3
May	2.32	0.5	0.5	0
June	3.92	0	0	0
July	2.43	1.75	0	1.75
August	3.39	0	0	0
Total	12.06	2.25	0.5	1.75

* 1 inch water = 22,622 Imperial gallons per acre.

Irrigation, 1959

Rainfall during the growing season, between the beginning of May and the end of August was the lowest recorded at Bodiam since 1949. Only 5.22 inches of rain fell during this period compared with an average of 10.67 inches in the previous five years. 2.51 inches of rain fell on 28th-30th July after the irrigation for that month was completed. 8 inches of irrigation were applied to the plots under treatment 1 which were irrigated from April to the

TABLE 2
RESULTS 1958
YIELD AND RESIN DATA
As determined by Arthur Guinness Son & Co. (Park Royal) Ltd.

Treatment (irrigation applied)	Dry hops at 10% moisture cwt./acre	Soft resins %	Soft resins cwt./acre
1. April to late August ..	18.8	9.2	1.76
2. April to mid-June ..	17.9	9.1	1.63
3. Mid-June to late August ..	21.2	9.0	1.91
4. No irrigation ..	21.8	9.3	2.04

end of August. Details of irrigation and rainfall are given in Table 3 and treatment yields in Table 4.

TABLE 3
IRRIGATION, 1959

Month	Rainfall in inches	Treatments Irrigation applied (inches of water)		
		1	2	3
May	0.84	1.25	1.25	0
June	0.80	1.0	1.0	0
July	2.91	1.25	1.25	1.25
August	0.67	1.5	0	2.5
		1.5	0	2.5
Total	5.22	1.5	0	1.5
		8.0	3.5	7.75

TABLE 4
RESULTS 1959
YIELD AND RESIN DATA
As determined by Arthur Guinness Son & Co. (Park Royal) Ltd.

Treatment (Irrigation applied)	Dry hops at 10% moisture cwt./acre	Soft resins %	Soft resins cwt. acre
1. April to late August ..	22.0†	8.2	1.8†
2. April to mid-June ..	20.9	8.1	1.7*
3. Mid-June to late August	21.5*	8.4	1.85‡
4. No irrigation (control) ..	18.9	8.0	1.5

Significantly different from control:

* ($P = 0.05$), † ($P = 0.01$), ‡ ($P = 0.001$).

In treatment 1, that is, hops irrigated from April to late August, an increase in yield of 3.1 cwt. per acre (16 per cent.) over the non-irrigated plots was obtained. Similarly hops irrigated from mid-June to late August yielded 2.6 cwt. per acre (13 per cent.) more than the control plots. Plots in treatment 2 which were irrigated from April to mid-June gave a smaller increase of 2 cwt. per acre over the control. The content of soft resins did not appear to have been influenced by the different irrigation treatments but the total production of soft resins was significantly higher in the irrigated treatments in all cases. The greatest increase occurred in the plots in treatment 3 irrigated from June to late August. This treatment showed an increase of 0.35 cwt./acre more than the control.

DISCUSSION AND CONCLUSION

The consistent rainfall throughout the growing season of 1958 probably nullified any real treatment differences which irrigation might have disclosed. In fact, the irrigated plots all yielded less than the non-irrigated. It is possible that the small amount of water applied in May and again in July, which was followed in each instance by a period of fairly heavy rain, may have resulted in some degree of leaching of nutrients from the soil to the drains and hence in the lower yields; or perhaps in temporary waterlogging with reduction of root range and nutrient uptake.

The growing season of 1959 was a complete contrast. With the exception of a heavy downpour in late July, very little rain fell between late April and harvest time in September. Under these climatic conditions a response to irrigation would be expected, particularly in the case of the plots irrigated in the latter half of the growing season. The plots irrigated mainly from mid-June to August produced the heaviest dry weight yields. During this period the overground portion of the hop was at its stage of maximum development and the demand for water and nutrients was also likely to be at its peak. Irrigation during this period may have assisted the development of the plant in two ways, by maintaining an adequate flow of water to replace that lost by the large area of transpiring leaves and by making available nutrients in the top 18 inches of soil at a time when the annual root system reached its maximum.

Despite the small amount of rain in May and up till late July, the bore hole readings showed that the water table did not fall below about four feet. In view of this a new site has been selected for subsequent trials.

The experiment in 1959 indicated that irrigation in June and July is likely to prove the most effective. Since 1959 was an exceptionally dry year, occurring in the past only once in about ten, it is probable that in years with a more normal seasonal rainfall, hop yields will give a smaller response to irrigation. This progress report may be helpful to growers at this stage in emphasizing the complexity of this type of work and the real danger of accepting some of the more extravagant claims being made. After a further two years a fuller report will be made.

PART II. COMMERCIAL IRRIGATION AT BODIAM

Records of crop yields have been accurately maintained over many years at Guinness Hop Farms Ltd. These offer valuable evidence of climatic and cultural trends upon crop yields. They cannot offer evidence of a type comparable with data obtained from scientific experiments since the control, i.e. the untreated plots essential in any experiment are, of course, absent. They do, however, suggest certain effects and in the present brief review, the evidence for and against irrigation is considered, both as a guide to growers and also to further emphasize the complexity of the problem and the interaction of other factors, notably soil type, cultivation and the age of the plant.

CROP YIELDS AND RAINFALL

In Table 5 the average yields per net acre of mature Fuggles between 1949 and 1959 are given for the Bodiam farms and for all other growths of this variety in Sussex and the Weald. Yields have been classified under four soil types in relation to hop growing:

A	Very good	Potential average yield:	18 cwt. or more per acre
AP	Potentially good	" "	16-18 cwt. per acre
B	Moderately Good	" "	14 cwt. per acre
C	Bad	" "	12 cwt. per acre

Gardens on "A" type soils are essentially those on slopes with soils in the Ladham and Teise series, while those on "AP" type soils are mainly flood plain gardens with alluvial soils in the Shaw series. Those on "B" type soils are on shallower, heavier land of the Lamberhurst, Benenden and Causton series, while the "C" type soils are those with shallower phases of the Lamberhurst, Benenden and Pembury series, probably with associated impeded drainage. The yield data can be examined in relation to rainfall for which data are included in Table 5.

TABLE 5

YIELD IN CWT. DRIED HOPS PER ACRE AND SUMMER RAINFALL IN INCHES FOR 1949-59 INCLUSIVE AT GUINNESS HOP FARMS LTD. BODIAM, SUSSEX. THE AVERAGE YIELDS FOR THE REST OF SUSSEX AND FOR THE WEALD OF KENT ARE ALSO INCLUDED. ALL YIELD, DATA REFER TO FUGGLES ONLY

Year	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Soil Grade A ..	13.8	20.5	16.2	13.2	17.2	17.6	17.0	12.9	17.7	19.1	21.3
Soil Grade AP ..	11.2	21.5	15.9	12.7	16.6	16.8	18.4	10.7	18.3	17.2	18.7
Soil Grade B ..	10.2	16.7	15.0	10.3	15.7	14.0	15.5	10.0	16.2	15.9	13.3
Soil Grade C ..	8.7	14.9	14.6	10.1	15.1	15.1	15.5	12.4	14.0	13.8	11.1
Average for Bodiam ..	10.9	18.4	15.4	11.6	16.2	15.9	16.6	11.5	16.5	16.5	16.1
Average for the rest of Sussex ..	13.3	19.8	15.9	12.3	13.1	12.0	13.8	9.5	15.2	15.2	11.5
Average for Weald of Kent	13.4	19.8	17.7	13.3	14.4	14.2	14.4	10.3	14.5	15.6	11.6
May ..	1.56	1.12	1.90	1.35	1.44	2.17	4.57	0.37	1.03	2.32	0.84
June ..	0.74	1.10	1.46	0.90	2.00	3.54	2.01	2.36	1.30	3.92	0.80
July ..	0.26	2.21	1.56	0.65	5.01	4.12	0.78	2.74	4.64	2.43	2.91
August ..	1.88	2.82	4.59	4.57	2.17	3.64	2.30	2.88	2.86	3.39	0.67
Total ..	4.44	7.25	9.51	7.47	10.62	13.47	9.66	8.35	9.83	12.06	5.22

The average age of the plant at Bodiam has been reduced in recent years and the general standard of management, particularly of cultivation and pest control, has improved. This is reflected in the fact that average yield since 1953 (Table 5) has remained at the relatively high value of 16-16.5 cwt. per acre with the exception of 1956 which is discussed below. Nevertheless the difference between the Bodiam yield in 1959 when a high percentage of the acreage was irrigated and all other farms in Sussex and the Weald, the majority of which were not irrigated, in a year when every hop was being picked, is very striking.

Marked falls in yield occurred in 1949, 1952 and 1956. In 1949 and 1952, rainfall in June and July was extremely small, only 1 inch in 1949 and 1.55 inches in 1952 and the low yields may be largely a reflection of this. In 1956, however, rainfall was higher and the low yield was due to damage by gales which occurred on 29th July and 6th August.

COMMERCIAL IRRIGATION

Yield data in 1958 and 1959 for a majority of gardens at Bodiam is shown in Table 6. The gardens have been grouped under the same soil types as in the previous table. Only yields from Fuggle hops three years old or more are given, and gardens which have clearly suffered from frequent machine picking are omitted. The amount of irrigation given in 1958 was small since 12.06 inches of rain fell in the period May to August. In 1959 a deficit of 8 inches had developed by the end of August and this far exceeded the quantity of water applied as irrigation over this period to the hops in a majority of gardens. It was not feasible, from the viewpoint of labour and availability of equipment, to irrigate gardens throughout the season and as can be seen, the quantities applied nowhere approached the calculated deficit. The comparison between 1958 and 1959 is therefore largely a comparison between a year in which it is probable that no water shortage was felt by the crop and one in which a limited amount of irrigation may have mitigated the effect of drought to some extent.

The beneficial effect of irrigation appears to have been most marked on the deeper good soils where water relations and soil structure may be presumed to have been such as to encourage the growth and penetration of annual feeding roots with consequent effective utilization of the increased amounts of nutrients made available by irrigation. Irrigation was least effective on the shallow B and C type soils where only in Great Barn and Redger Gardens

TABLE 6

IRRIGATION (INCHES OF WATER) APPLIED IN 1958 AND 1959 ON GUINNESS HOP FARMS LTD. AT BODIAM, SUSSEX, AND INCREASE OR DECREASE IN YIELD (CWT. DRIED HOPS PER ACRE) IN 1959 COMPARED WITH 1958

Garden	Age in 1959	Yield Diff. Cwt./net acre 1959 minus 1958	Irrigation (inches)	
			1958	1959
Soil A				
Curtain Meadow	5	6.9	0	2
Hope	6	4.9	0	2.25
Shinmoor	9	3.0	0.75	2
Ladham	10	4.1	0.75	3
Nine Acres	14	0.7	0	2
Road	14	5.3	0	2
Seven Acres	33	1.8	0	2.25
Soil A				
East Church Field	11	-7.5	1	2
Coopers	16	-1.4	0	2
Upper Brook	16	-3.3	0	3
Soil AP				
Park Longbrook	4	3.9	0	2.25
Crainham	5	3.3	0.75	2
Calf Lodge	5	2.0	0.75	3.25
Stainsmoor	8	2.6	0	1.25
Baybrook	8	3.0	2.25	8
Broadbrook	9	2.5	0	2.25
Pell Brook	9	3.4	0	2.25
Copses	16	1.1	0	3.50
Soil AP				
OxPasture	3	-1.3	1.5	2
Brooks	3	-3.5	1	4
Garil Meads	3	-1.3	0	2.25
Footway	15	-5.4	0	5
Chequer Brook	16	-1.6	0	2
Middlebrook	25	-3.9	0	4
Soil B				
Great Barn	3	1.8	0	5
Soil B				
Holmans	7	-2.9	0.75	2.25
Westwood	7	-0.7	0	2
Mortar Field	8	-2.6	0.5	1
Fowl Brook	9	-1.4	0	2
Wellhead	9	-1.4	0	2.50
Highfield	10	-6.2	1	2.25
Long Field	13	-2.2	0	1.50
Park Meadow	14	-2.2	0	4
Neblongs	15	-9.0	0	1
Wild Goose	15	-2.5	0	3
Spring Field	20	-3.6	0	1

TABLE 6—continued

				<i>Soil C</i>		
Redger	..	..	7	0.7	0	5
				<i>Soil C</i>		
Grub Ground	..	..	6	-9.1	0.75	2
West Church Field	..	..	16	-6.0	1	2.75
Pond	..	..	25	-0.3	0.75	2

<i>Rainfall, 1958</i>				<i>Rainfall, 1959</i>		
May-August, 12.06 inches.				5.22 inches		

were increases in yield recorded in 1959. Here 5 inches of water were applied in both gardens during May-August compared with an average of about 2 inches for other gardens in these two soil groups.

This apparent relationship between soil type and response to irrigation is indicated by the following average figures for differences in yield of mature Fuggles obtained by summarizing all the data available at Bodiam for 1958 and 1959:

Soil type	Yield difference 1959 minus 1958 (cwt. per acre)	Average irrigation (inches per acre)	
		1958	1959
A	2.2	0.5	2.0
AP	1.5	0.5	2.75
B	-2.6	0.25	2.0
C	-2.7	0.5	2.0

IRRIGATION OF YOUNG PLANTS

Irrigation has been applied to young plant, and the yields obtained in one and two-year-old gardens in 1958 and 1959 are given overleaf.

It is possible that young hops are more comparable with an annual crop, such as lettuce, in that they are building up a root system which is initially shallow. They are, therefore, likely to be sensitive to a small water deficit and the ample water which can be given by irrigating will assist the development of a good root system as well as making available nutrients so that vigorous growth is maintained and maturity hastened.

CONCLUSIONS

Commercial irrigation of young plants up to three years may greatly assist establishment and increase yield particularly when May and June are exceptionally dry.

Garden	Age in 1959	Yield cwt./net acre		Irrigation (inches)	
		1958	1959	1958	1959
<i>Soil A</i>					
Eight acres ..	1	—	5.5	—	6
Maple Garden* ..	1	—	8.4	—	6.25
Hilly Field* ..	2	6.4	20.3	.75	1
Maple Garden ..	2	7.7	22.3	.75	3.25
<i>Soil AP</i>					
West Meadow* ..	1	—	15.6	—	4
Old Longbrook*	1	—	8.8	—	5
Garil Meads ..	2	12.5	24.2	—	2.25
Five Acres ..	2	11.0	20.8	—	2
Curtain Brook* ..	2	13.1	31.0	1	1
<i>Soil B</i>					
Moorbeds ..	1	—	9.5	—	5

* Wye varieties.

With mature hops, the greatest effect appears to have been found on the deeper soils of better texture. The economics of this—i.e. whether the increase in yield justifies the cost of irrigation—varies from season to season. Growers must form their own opinions on these matters. Irrigation effects will be modified by soil type, drainage, age of plant and time of application. These results should be treated with great caution since it is possible that the effects observed could be attributed to causes other than irrigation.—Scientific opinion must await the completion of the experiments now in progress at Bodiam and elsewhere which still require a number of years for their full assessment.

ACKNOWLEDGMENTS

The co-operation of Guinness Hop Farms Ltd., in providing the land and equipment for the irrigation experiment is gratefully acknowledged. Thanks are also due to the members of staff at Bodiam for carrying out the experiment, particularly to Mr. H. Roberts and to Miss A. Chavasse, and to Miss S. V. Cunliffe for the statistical layout and analysis of results.

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NOTE ON A SHORT EXPERIMENT ON THE STRENGTH OF HOP ANCHORS—WYE, MARCH, 1960

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SUMMARY

Tests were carried out at Wye College in which hop anchors were pulled out of brickearth-type soil by a winch acting through a rocker system giving the same direction of pull as a standard anchor wire. Dynamometer recordings showed that seven new anchors of the standard wood block (dead man) type failed at an average maximum load of 7,900 lb. which is well above the yield load of new anchor wire (4,500 lb.). Proprietary anchors, based on circular 6 in. diameter steel plates instead of wood blocks, failed at an average maximum load of 2,800 lb. The data made available by the tests have been examined in the light of soil mechanics theory and tentative suggestions are made in the appendix as to the relative importance of the variable factors concerned in the performance of a hop anchor.

INTRODUCTION

The pole and wirework systems of English hop fields follow a standard pattern, in which the strengths of the various components seem to have been arrived at empirically, probably as a compromise between the high cost of wirework sufficiently strong for failure never to occur and the losses which would occur if very light components led to frequent failures. The occasional failures which do occur presumably constitute an acceptable risk, but the trend towards higher wirework to produce a habit of growth suited to machine picking has posed the question whether the

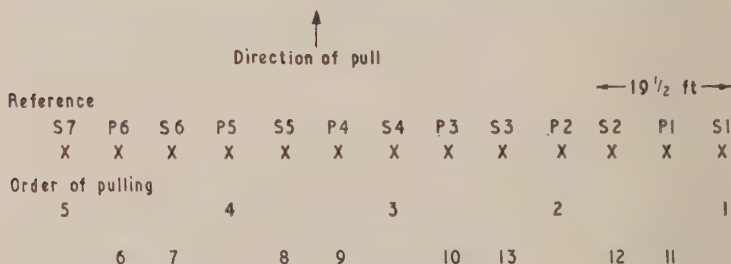


FIG. 1
Plan of site.

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gauges of wire, and the anchor dimensions normally recommended will still be safe with the greater heights. Enquiries from a number of growers suggest that serious failures of wirework are most often initiated by the breaking of an anchor wire, or occasionally by the pulling of anchors. An experiment was initiated in 1959 in which tensions in anchor wires of wirework of different heights are being measured continuously through a number of seasons, and this will be reported elsewhere.

In addition, in 1960, an opportunity arose to measure the strength of some anchors in new condition at Wye College. The available anchors were of two types; first, standard anchors in which 54 in. galvanized rods were passed through 30 in. by 6 in. half-round chestnut blocks known as "dead men" and the latter buried to a depth of 30-36 in.; second, proprietary anchors consisting of galvanized rods of similar length to the standard anchors but with steel plates in the form of a short helix of 6 in. diameter attached at their feet. In both types of anchor the rods, when buried, were inclined at 45° to the horizontal, being directly in line with the anchor wires attaching them to the wirework system as shown in Fig. 2. When burying each dead man, care was taken to ensure that the flat bearing surface, which was at right angles to the rod, rested against a carefully cut undisturbed soil face. The proprietary

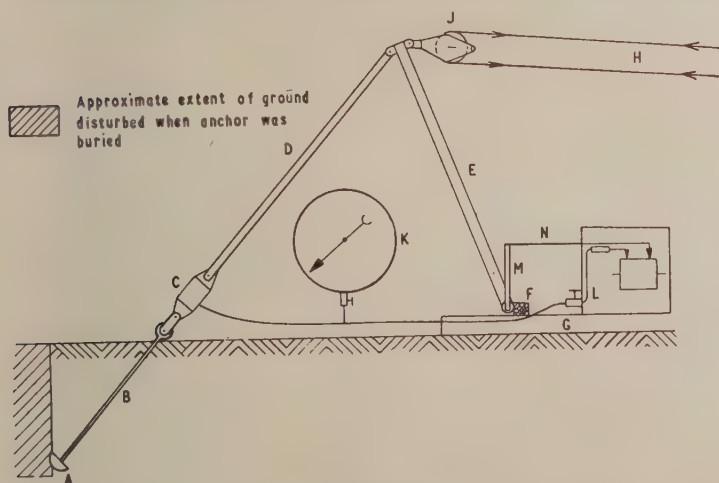


FIG. 2
Arrangement of apparatus.

anchors were screwed into the ground by means of a special tool until their plates were at the same depth as the dead men of the standard anchors.

EXPERIMENTAL

The soil in which the anchors were buried was a brickearth overlying chalk downwash material (coombe deposit). Fig. 1 shows the plan of the site giving the relative location of the various anchors and the order in which they were pulled. The prefix "S" denotes a standard anchor and "P" a proprietary anchor. Fig. 2 shows the arrangement of the apparatus. The dead man (A) and anchor rod (B) were connected by an N.I.A.E. 40,000 lb. dynamometer link (C) and a 6 ft. long tension link (D) (roughly parallel with the anchor wires in the field) to a rocker (E). The rocker was of inverted "T" form, with its cross bar resting against blocks (F) on sleepers (G). A pull was applied to the top of the rocker by cables (H) from a tractor winch by a pulley block (J). The resulting pull on the anchor was registered by a large pressure gauge (K), arranged to be visible to the winch driver, and by a pressure recorder (L). The approximate distance that the anchor moved was transmitted to the recorder by a 15 in. crank arm (M) attached to the rocker, and a length of cord (N).

RESULTS

Curves of load against deflection are given in Fig. 3-6. Fig. 3 shows the results obtained with three standard anchors pulled from ground which was undisturbed for a distance of about 30 ft. Fig. 4 shows the results obtained with four standard anchors pulled from ground which may possibly have been affected by the disturbance caused by the pulling of adjacent anchors. Fig. 5 shows the results obtained with two proprietary anchors pulled from undisturbed ground and Fig. 6 the results obtained with three proprietary anchors pulled from ground which again may possibly have been disturbed. The results are summarized in Table 1, which besides the maximum loads shows the anchor movement at soil yield, at 4,500 lb. (the yield point of 7×00 gauge anchor wire when new) and at 1,000 lb. (the approximate mean load measured in 1959 in anchor wires in the height of wirework experiment).

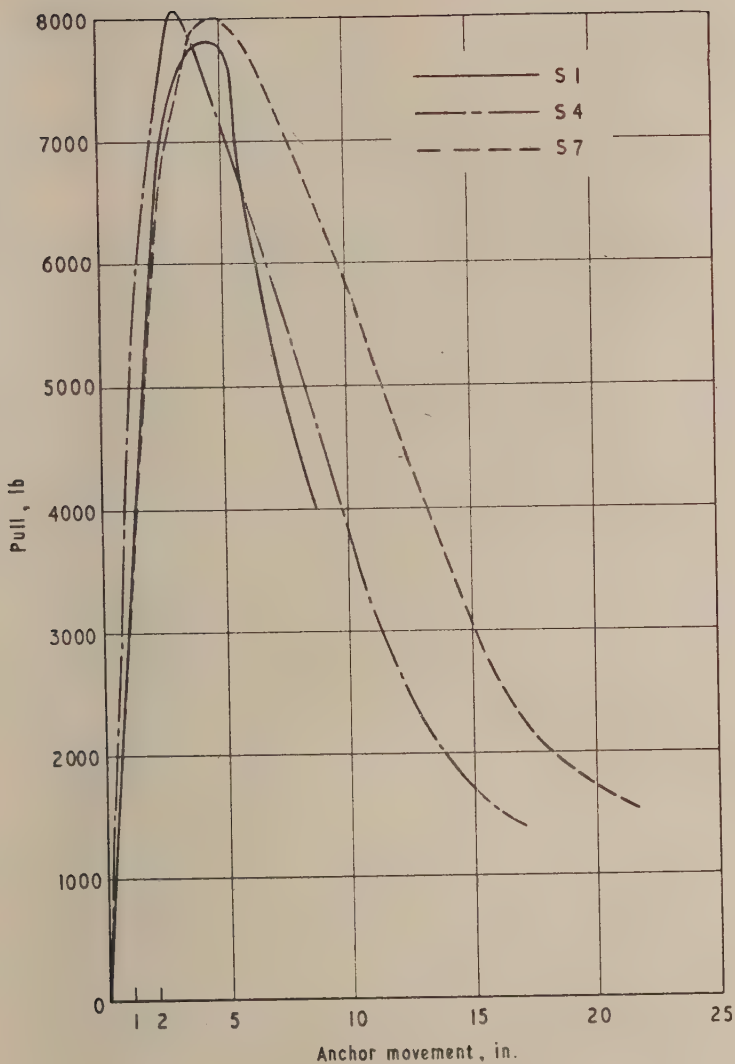


FIG. 3
Standard hop anchors of dead man type: curves of load against deflection for three anchors (S1, S4 and S7) pulled from undisturbed soil.

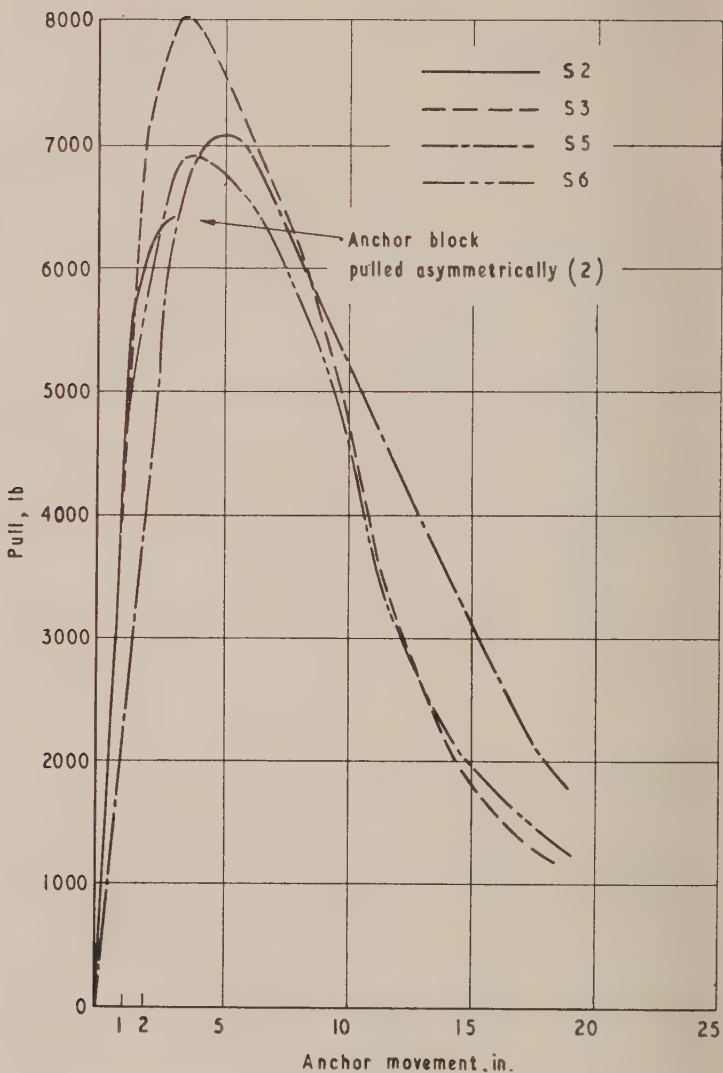


FIG. 4
Standard hop anchors of dead man type: curves of load against deflection for four anchors (S2, S3, S5 and S6) pulled from soil that may have been disturbed.

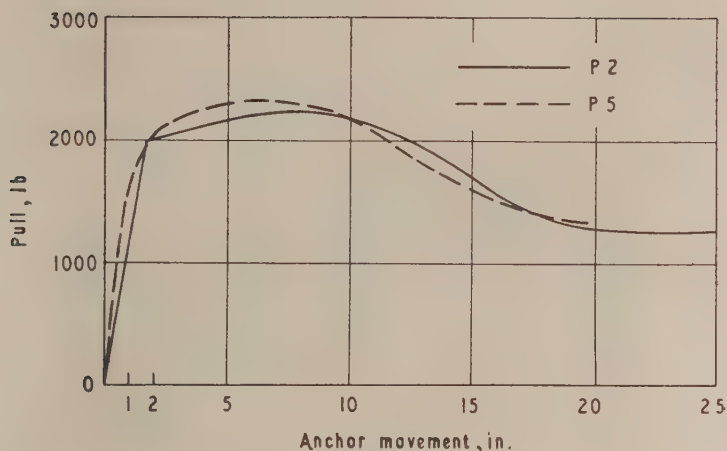


FIG. 5

Proprietary hop anchors with 6 in. diameter circular steel plates: curves of load against deflection for two anchors (P2 and P5) pulled from undisturbed soil.

TABLE 1

Anchor No.	Maximum load (lb.)	Soil yield load (lb.)	Movement before yield (in.)	Movement at 4,500 lb. (in.)	Movement at 1,000 lb. (in.)
S1	7,800	6,500	2.2	1.5	0.34
S2*	6,400	5,400	1.2	1.0	0.22
S3	8,050	6,000	1.5	1.1	0.25
S4	8,050	6,000	1.5	1.1	0.25
S5	7,100	6,000	2.7	2.0	0.45
S6	6,900	5,200	1.3	1.1	0.25
S7	8,000	6,500	2.3	1.6	0.35
Mean	7,400	5,900	1.8	1.3	0.32
P1	2,650	2,000	0.9	—	0.45
P2	2,250	2,000	1.7	—	0.85
P3†	2,300	1,500	0.8	—	0.53
P4‡	3,650	3,000	2.2	—	0.73
P5	2,350	1,500	0.7	—	0.47
P6	—	(record not completed)			
Mean	2,800	2,000	1.3	—	0.61

* The soil upheaval while pulling S2 was asymmetric and the anchor rod bent at the block, until the latter was almost in line with the rod.

† The plate of P3 was slightly buckled.

‡ P4 was screwed in alongside a large stone, and the plate was completely sheared off the rod as the anchor pulled out.

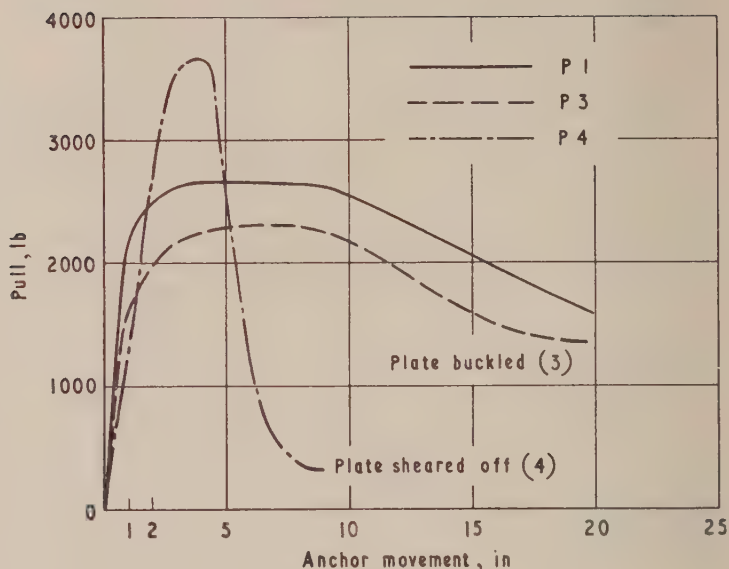


FIG. 6
Proprietary hop anchors with 6 in. diameter circular steel plates: curves of load against deflection for three anchors (P1, P3 and P4) pulled from soil that may have been disturbed.

The first visible sign of soil disturbance around the standard anchor was the appearance of a shallow blister on the surface. Cracks appeared in the soil at about the yield load and by the time the anchor would no longer sustain its maximum load it was clear that a block of soil of roughly the shape shown by the heavy lines in Fig. 7 had been isolated from the main bulk of the land. Measurements of the isolated block of soil were made and are given in Table 2. Plate 1 shows the appearance of the soil disturbance after the completion of the pull on the standard anchor S5.

The proprietary anchors failed with relatively little soil disturbance and measurements made after the soil failure showed the area appearing on the surface to be roughly circular in form, with a mean diameter of between 10 and 17 inches.

CONCLUSIONS

It should be noted that the experimental results are only valid for the particular soil on which the trials were made; however,

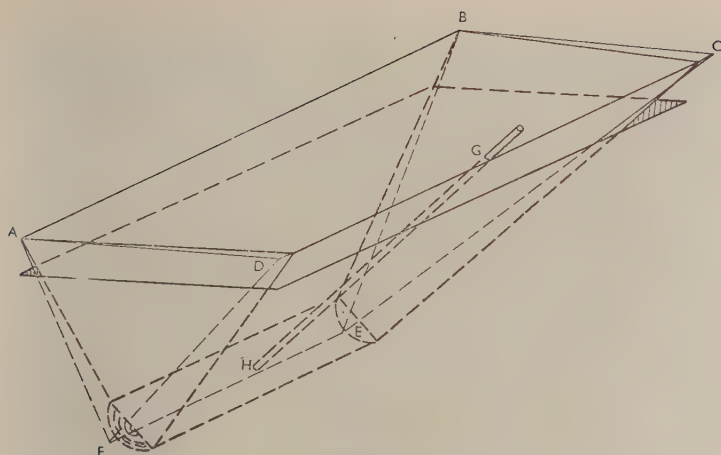


FIG. 7

Assumed and measured shapes (thin and thick lines respectively) of soil block moved at point of failure of standard hop anchor of dead man type.

TABLE 2

Anchor No.	Dimensions of soil block, inches				
	AB	CD	BC	AD	GH*
S1	49	45	30	30	39
S2	61	61	—	—	—
S3	63	55	30	31	—
S4	58	54	30	36	42
S5	54	43	32	28	40
S6	65	63	32	28	—
Mean	58	54	31	31	40

* GH, the length of the anchor rod from the upper surface of the anchor to the soil surface, is based on the soil marks on the rods, where clearly discernible.

it is considered that apart from the presence of a few large stones in one part of the field which affected one of the proprietary anchors, the soil was, if anything, mechanically weaker than many soils on which hops are grown.

The standard anchors of the dead man type all failed at a load considerably in excess of the ultimate strength of new anchor wires of 7×00 gauge, and soil yield was well in excess of the yield load of the wire. It should be borne in mind, however,

that the anchors were all in new condition, and failure might occur at lower loads with old anchors because of rotting of the anchor blocks or corrosion of the rods. Corrosion of the wires themselves might also lead to a reduction in strength. If the opportunity offers, measurement of the strength of wirework and anchors at the end of their useful life will be undertaken.

The proprietary anchors failed at a load considerably below the yield load of the 7×00 anchor wires. As the plate sheared off one anchor (which was more firmly held by the ground than the rest) at a higher load but still well below the yield load of the anchor wires, it appears that the particular size of anchor tried would introduce an element of risk not present with new anchors of the dead man type. It is understood that the manufacturers propose in future to supply anchors fitted with a larger helical plate for application to hop wirework.

APPENDIX

CALCULATION OF THE EFFECT OF CHANGES OF ANCHOR DIMENSIONS

Although the foregoing experimental results give information on the magnitude of the maximum load which can be sustained by two distinct types of anchor, they give no indication of the effects of variations in the proportions of the anchorage. In the absence of experimental evidence, it has been thought worth while to estimate on a semi-theoretical basis the probable effects on the ultimate strength of an anchorage of the dead man type of changing width, depth, and inclination of anchor rod.

The procedure adopted in making these estimates was to regard the shape of the soil block isolated on failure as a right triangular prism with inclined end surfaces, indicated by light lines in Fig. 7. The mean ultimate load from the experiment could then be equated to the sum of the shear forces acting on the faces ADF, BCE and CDFE and that component of the soil's weight which acts along the anchor rod. The faces ADF and BCE are nearly vertical and therefore the frictional component of the shear forces acting on them was regarded as negligible, whereas both cohesive and frictional components were considered for the inclined surface CDFE. Making use of the simplifying assumptions stated below it follows that the soil cohesion was approximately $2\frac{1}{2}$ lb. per sq. in., which is compatible with the soil type; the probable effect of changing the following dimensions of the anchorage would be as depicted by the curves in Fig. 8:



PLATE I
Soil disturbance following failure of standard hop anchor of dead man type.

- (i) The width of the dead man—Curve A.
- (ii) The depth of the dead man; the inclination of the anchor rod remaining constant and its length therefore being altered to suit—Curve B.
- (iii) The inclination of the anchor rod; depth remaining constant and length of anchor rod therefore being altered to suit—Curve C.
- (iv) The inclination of the anchor rod to the horizontal; length remaining constant and depth therefore altering—Curve D.

Confidence in the Shape of the Curves must Decrease with Increasing divergence from the Experimental Values, as the Degree of Approximation in the Simplifying Assumptions then Increases.

Curve A is of interest in connection with the possible rotting of the ends of the dead man in the course of time; the inference is that the strength of the anchor is not reduced in proportion as the length of the dead man is decreased. However, the proviso of decreasing confidence with increasing divergence from experimental results must be borne in mind, for the curve if produced back gives a decidedly optimistic estimate for the strength of the proprietary anchors.

Curve B emphasizes the great sensitivity of the strength of the anchorage to its depth.

Curve C shows that with constant depth of anchorage, a decrease in the angle between the anchor rod and the horizontal would add to the strength of the anchorage and conversely an increase in this angle would detract from the strength of the anchorage: thus, if wirework of increased height were erected without increasing headland width or anchor depth from the values previously used, the anchorages would be weaker. If on the other hand the length of buried rod remained constant, necessitating a change in the depth of the anchorage (curve D) the loss of strength due to the steeper angle would be approximately offset by the greater depth.

ASSUMPTIONS

1. The shape of the volume of soil isolated by the shear surfaces when an anchor of the dead man type fails is a right triangular prism—ABCDEF, Fig. 7—except that the triangular end surfaces,

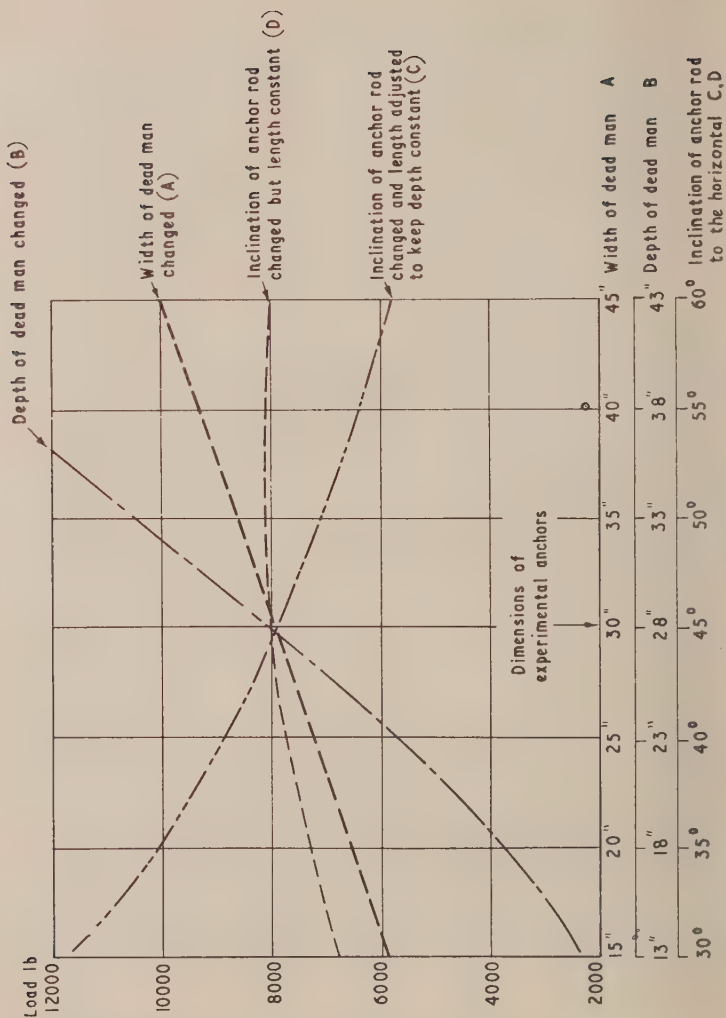


FIG. 8

Curves giving calculated relationships between variable dimensions of hop anchors and maximum load.

ADF and BCE are inclined to the vertical so as to make the length of the prism least at the greatest depth.

(The extent to which the assumed shape differs from the measured values is indicated in Fig. 7 in which the thick lines

represent the measured shape and the thin lines the assumed shape.)

2. The inclination of the surface CDFE to the horizontal remains the same as that of the anchor rod for all values considered.

3. The inclination of the triangular end surfaces is independent of changes in the other quantities.

(This has been found to be true in the case of inclined tines (Payne and Tanner, 1959) to which the anchor bears a close similarity.)

4. The tensile strength of the soil is zero and the maximum shear strength obeys Coulomb's Law which may be stated in the form— $s = c + \sigma \tan \phi$, where,

s = maximum shear strength of soil.

c = cohesive strength of soil.

σ = normal stress acting on shear surface.

ϕ = angle of shearing resistance of soil.

(This has been found to be true for most agricultural soils, (Payne, 1956)).

5. The volume/weight of the soil has a value of 0.06 lb./cu. in. (This value is likely to be correct within the limits ± 15 per cent.)

6. The angle of shearing resistance of the soil has a value of 30° . (A value close to this is likely on the soil type used in the experiments (Payne, 1959) and even if incorrect would not substantially alter the shape of the curves in Fig. 7.)

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WYE COLLEGE HOP CONFERENCE: JANUARY 1960

INTRODUCTION

H. S. DARLING

A SUCCESSFUL one-day conference for hop growers was held at Wye, Kent, on 6th January, 1960, to discuss the results of recent hop research at Wye College. About 250 visitors were present, the majority being growers of which a number had travelled from the West Midlands for the occasion. Factors, merchants, brewers and other branches of the Hop Industry were also represented.

In opening the conference, Principal Dunstan Skilbeck emphasized the historical link between Wye College and research on hops. As far back as 1894, the then principal, Sir Daniel Hall, had carried out cultural and manurial experiments with the crop which had yielded results of lasting value. In 1947 this work was reorganized into the Department of Hop Research under Dr. A. H. Burgess who was followed by Dr. H. S. Darling, appointed as successor to Dr. Burgess in 1954.

The conference comprised three sessions in each of which two papers were read. Chairmen of these sessions included Dr. F. R. Tubbs, Director of East Malling Research Station and Mr. B. D. Neame a well-known hop grower from Faversham, Kent. Among the growers who took a prominent part in the discussion on the six papers were Mr. S. G. Calcutt of Cranbrook, Kent, Mr. J. Nott of Tenbury Wells, Worcestershire, and Mr. J. F. Brown of Guinness Hop Farms Ltd.

In the course of the conference opportunity was taken to present the Order of the Hop to members of the Hop Industry to which this European Order had recently been awarded. These comprised Mr. S. R. Allsopp, Chairman of the Hops Marketing Board, Mr. Arthur Amos of Wye, Kent, and Mr. James Nott of Tenbury Wells, Worcestershire. Mention was also made of the award of the Order to Professor E. S. Salmon, Fellow of Wye College, who died in October, 1959, before the decoration could be presented to him.

The opening paper of the conference was read by Dr. H. S. Darling. This paper discussed the work of the Department in

general terms and its substance is embodied in the Review of Research on page 7 at the beginning of this report. The remaining five papers presented at the Conference are given below in part or in full. All are concerned with current research on hop problems carried out at, or in collaboration with, Wye College. The authors are members of the College with the exception of Mr. P. H. Bailey who is on the staff of the National Institute of Agricultural Engineering.

PAPER 2.

HOP MANURING: RESULTS OF RECENT RESEARCH

F. C. THOMPSON

(The following is a summary of the paper presented, the substance of which is published in full in the *Journal of Horticultural Science* for July, 1960, Vol. 35, p. 185, under the title "A long-term manurial experiment with hops".)

IN spite of work done in the past there is still much to be learnt about the manuring of crop plants, and this includes hops. This is largely because the soil is itself a natural reservoir of plant foods, the supply of which can vary considerably from one soil to another, not only in terms of total nutrients but, and of far more importance, in the availability of these nutrients to plant roots.

Laboratory tests can give some measure of the availability of plant nutrients in soil and, in particular, satisfactory tests have been evolved for the assessment of available phosphate and potash. These laboratory tests are, however, essentially empirical and the results obtained only begin to have meaning when calibrated by field trials in which the yield response of a crop to different fertilizer treatments is measured, and soil samples are taken for analysis from the plots receiving the different treatments.

With the hop plant, experimental work on manuring was carried out by Dr. Burgess at Wye, in the pre-war years, and he evolved a valuable scheme of manurial recommendations. But his work was not specifically related to soil analysis, which pre-war had not been developed extensively, so there was need for further manurial trials for calibration purposes and the first of these was started some ten years ago.

This first trial was laid down in Sussex on land which had not previously carried hops and which was in a low state of fertility. Superimposed on an annual basal dressing of dung, a number of different fertilizer treatments were tested, including very high levels of superphosphate and muriate of potash compared with much lower levels of these fertilizers, as then recommended by Dr. Burgess. Big responses in crop yield were obtained to both high phosphate and high potash manuring, when the levels of available phosphate and potash in the soil were low. Yield response decreased markedly,

however, as the levels of soil available phosphate and potash rose to the "very high" category, when the response became negligibly small or even, in the case of potash, negative, resulting in a loss of yield.

The levels of available phosphate and potash are very high in many, if not in the majority, of established hop gardens. In such cases, where dung is used, there is a lot to be said for cutting out phosphate and potash altogether for a year or two, but if we want to be cautious, then at least reduce them to not more than 2 to 3 cwt. per acre superphosphate and 1 cwt. muriate of potash.

PAPER 3.

CHANGES IN THE CARBOHYDRATE BALANCE OF THE HOP (*HUMULUS LUPULUS* L.) IN RELATION TO THE ANNUAL GROWTH CYCLE IN YOUNG PLANTS

I. H. WILLIAMS

SUMMARY

An experiment is described which was carried out in the open using pot-grown plants of the variety Fuggle. Chemical analyses of the storage organ throughout the year showed that carbohydrate accumulation and depletion is closely related to changes in the annual growth cycle of the plant.

INTRODUCTION

The results of a preliminary glasshouse experiment (Williams and Weston, 1959) showed that with hop plants propagated from soft-wood cuttings, little reserve carbohydrate accumulated in the rootstocks when the shoots were elongating actively. In similar plants that had ceased to elongate and were in the process of going dormant, reserves were built up rapidly by a relatively small leaf area. Analysis of these carbohydrate reserves showed that the primary storage material was starch.

The present paper discusses the extension of this work to a study of carbohydrate storage changes in hop plants derived from rooted setts and grown for a year in large pots out-of-doors in the natural environment of south-eastern England.

MATERIALS AND METHOD

Trimmed setts of variety Fuggle N were used. Plants were set out in John Innes potting compost No. 3 in 12½ inch pots in the open in late March, 1959. Irrigation was given throughout and liquid nutrients based upon the recommendations for hops (Thompson, 1956) were given as required. No cultural treatments were imposed.

From April onwards five plants were examined at weekly intervals. Chemical analyses of the storage organs for starch and reducing sugars were made according to the method described in the previous paper (Williams and Weston, *loc. cit.*); this work was

carried out under the direction of Mr. E. W. Weston whose help in this matter is gratefully acknowledged.

The term "starch" has been used to describe the storage polysaccharides. The sugar resulting from the hydrolysis of reserve polysaccharides was mostly glucose in samples of high "starch" content. Recent examinations by Mr. J. B. Roberts of this Department, using paper chromatography, has indicated the presence of fructose, xylose and arabinose in addition to glucose in all samples.

Detailed growth analyses were carried out on both roots and shoots. From these data it was possible to relate changes in the carbohydrate level with seasonal changes in the growth and development of the plant.

RESULTS

The annual growth cycle of the hop can be conveniently studied by dividing it into four main phases of growth and considering the changes which occur in the food storage levels during each phase.

The Vegetative Phase

This phase started in late March or early April when the dormant buds below soil level began to elongate and concluded when flower initiation occurred in June. During this period the primary shoots attained a length of between twelve and fifteen feet (3.5-4.5 metres). Primary leaves were formed, their development lagging behind shoot growth in the earlier stages (Fig. 1). Some new roots developed from the parent sett during this phase. These roots were relatively few in number and showed little branching.

The bedded setts had an initial starch content of about 15 per cent. or 3 gm. per sett (Figs. 2 and 3). This reserve fell to nearly zero in April and May and was probably utilized as energy for the considerable shoot development. In early June a consistent though small increase of reserves was recorded rising from 3 per cent. to 12 per cent. at the beginning of July. This was concurrent with the increasing rate of expansion of new leaves and a consequent increase in photosynthetic capacity.

The Reproductive Phase

Flower initiation in early June occurred first in the axillary meristems towards the apex of the primary shoots. The terminal

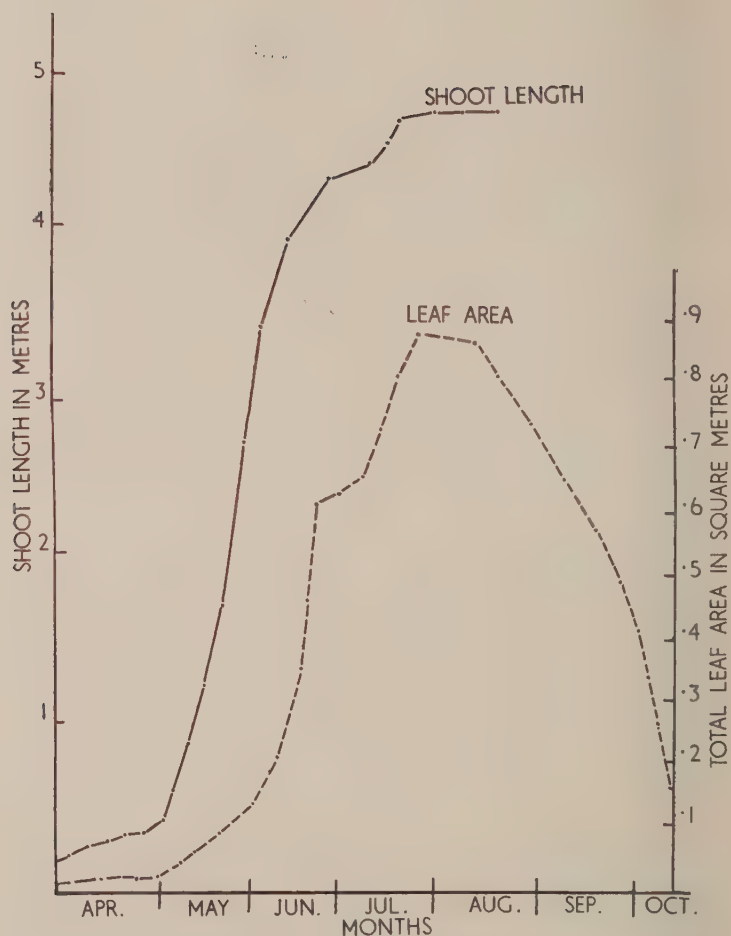


FIG. 1
Shoot elongation and leaf area: young hop plant

meristem itself formed the terminal inflorescence and ultimately the terminal cone. During this period there was increasing emphasis upon lateral development which continued throughout July. Laterals comprised both flowers and leaves with a consequent increase in the photosynthetic capacity of the plant. Throughout

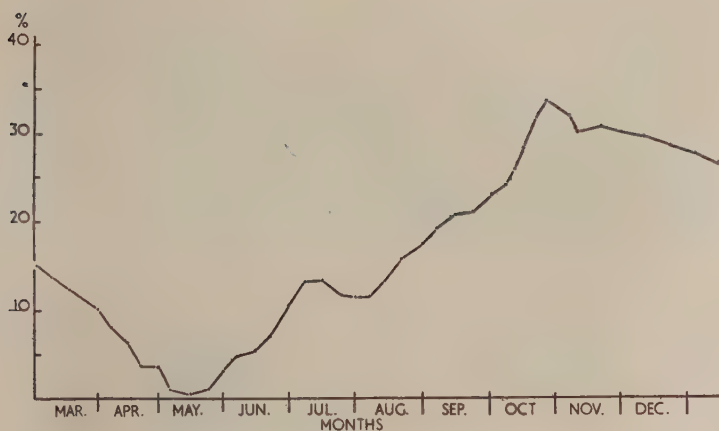


FIG. 2
% starch in the storage organs of young hop plants

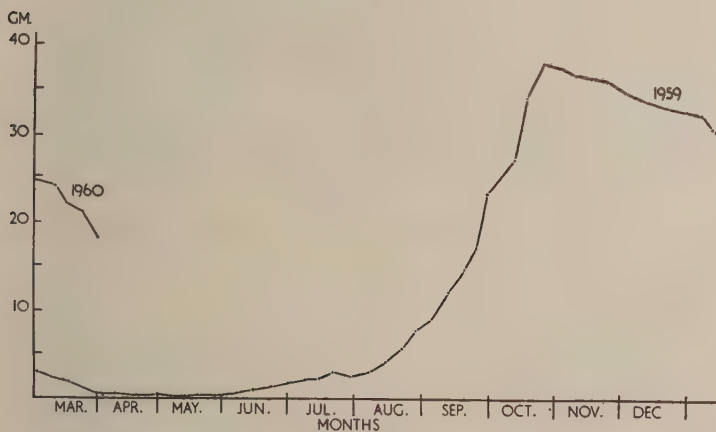


FIG. 3
Total starch in the underground storage organ of young hop plant

August development was mainly confined to cone and seed formation.

Throughout this phase there was extensive root development. These roots were produced from existing roots and also from the

buried portion of the new primary shoots. They were fine, branching roots which ramified throughout the soil.

Starch accumulation continued in early July. The increase in total starch was, however, small, from less than 1 gm. per sett in early June to 3.1 gm. at the beginning of July (Figs. 2 and 3). During the period of late July and early August the food reserves fell from 15 per cent. to 12 per cent. which may have been due to the extensive lateral and cone development during this period, shown by the dry weight figures (Fig. 4).

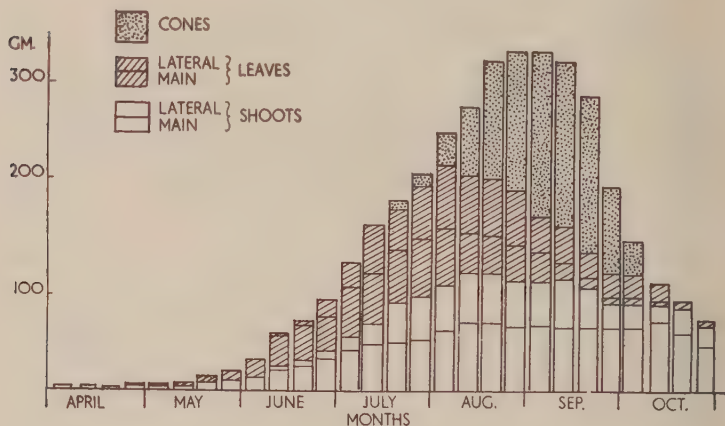


FIG. 4
Growth of overground portion of young hop plant—dry weight

The Onset of Dormancy Phase

The ripening of cones in early September was followed by the gradual senescence of the overground shoot system. Leaves remained viable until late October. No new leaves or new shoots developed during this period. October was unusually warm and sunny in 1959 and this may well have prolonged the effective life of the shoots and leaves. In early November the entire shoot system died back to soil level. During this phase, the finer roots also died but the thicker perennating roots increased in diameter.

The rate of starch accumulation was at a maximum during this period, percentage starch reaching 33 per cent. and total starch 38 gm. per sett. Depletion began in late October.

The Dormant Phase

The overwintering, or dormant phase of the plant began with the death of the shoot to soil level. During this phase the plant consisted essentially of the perennial storage roots, the old portion of stem which comprised the original sett and the new portion of stem up to soil level. Also, the dormant buds which would form the following year's shoots could be seen upon both the new and old stem portions (Fig. 6). During the winter period, there was a gradual decline in the food reserves which fell from 33 per cent. in

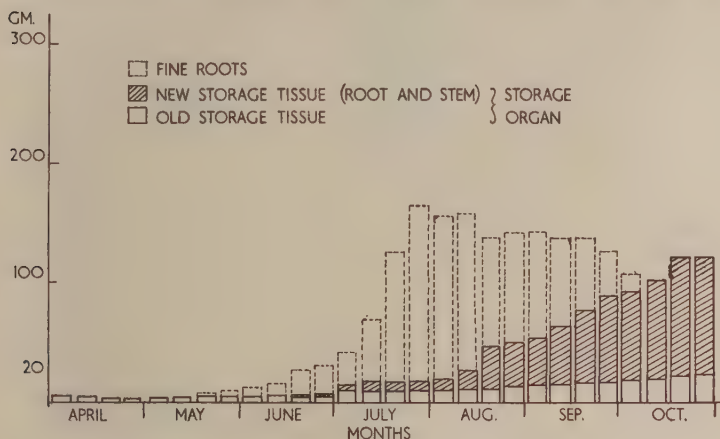


FIG. 5
Growth of underground portion of young hop plant—dry weight

October to 12.5 per cent. in early April; the rate of decline increased a little during early March and April. There was a complementary increase in soluble sugars during this latter period. Some starch was probably utilized to maintain the plant during the winter, whilst some was converted to sugar in the spring as a prelude to shoot growth.

The dry weight figures (Figs. 4 and 5) summarize the growth and development of the plant throughout the year. Also changes in total leaf area (Fig. 1) can be regarded as a guide to the current photosynthetic capacity of the plant and hence its capacity to build up carbohydrates. By comparing these with the data for total and percentage starch it is possible to outline the seasonal changes and utilization of food reserves.

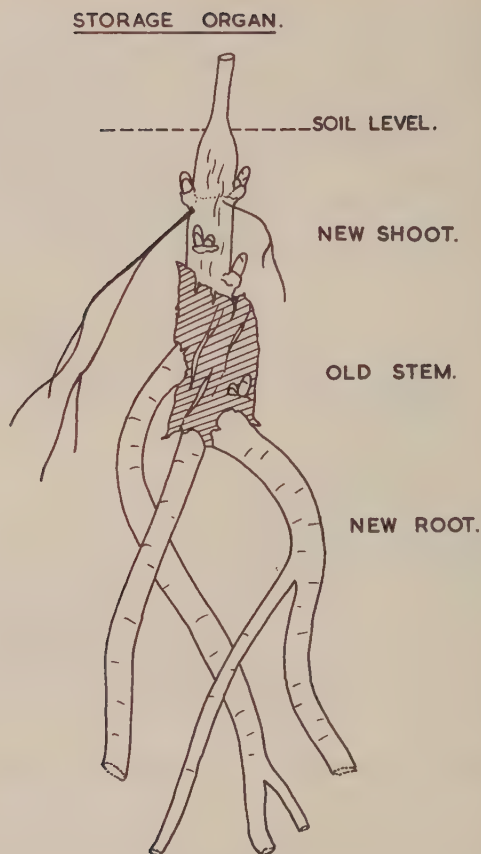


FIG. 6
Perennial storage organ of young plant consisting of new shoot, old stem of original trimmed sett and new storage roots

DISCUSSION AND CONCLUSIONS

Photosynthates produced by the leaves may be used either as a source of energy for current processes, including growth and development, or converted into storage material for subsequent use.

The primary functions of the storage material would seem to be, first, to enable a sufficient part of the plant to survive during the winter period, when no photosynthesis is possible; second,

to supply energy to initiate and sustain shoot growth during the early part of the vegetative phase. During this phase, the essential over-ground framework is laid down which will carry both leaves and cones. In this experiment the depletion of reserve carbohydrate ceased in June as leaves increased in number and effectiveness. Hamaguchi (1955) noted a depression in growth rate of the primary shoots in the latter part of May. He suggested that this was due to "a turning point from usage of reserves to independent nutrition". The present study did not confirm this; there was no apparent fall-off in the rate of shoot growth in May and it seems more likely that the utilization of reserves and their accumulation is a gradual process, without marked changes. Hamaguchi recorded a second check in the rate of shoot elongation, which occurred in late June and coincided with flower initiation. This was observed with plants grown in the present experiment (Fig. 1).

Starch accumulation was small in June and July, and utilization of reserves may well have continued during this period. The development of laterals and cones in July and throughout August represented the maximum period of annual growth, and was reflected in a slight fall in the starch reserves. Effective leaf area also attained a maximum during this period.

With the onset of dormancy growth and development ceased. This has been shown to be primarily a day length response (Williams and Weston, 1959). Vegetative elongation was shown to be inhibited by short days in early September even under the cool glasshouse conditions of the experiment referred to. During the period from September until the death of the overground shoot the hops continued starch accumulation. Light and temperature conditions in the autumn of 1959 were unusually good and the late accumulation of food reserves may be exceptional.

In New Zealand, Monk (1958) carried out a limited analysis upon mature plants in the field. He sampled 14 "hop roots" over a period of 14 months, each sample consisting of an unspecified quantity from "two hills". His conclusions were that during growth there was a gradual build up of starch with a decrease in the starch content of the cortex during the early months of the growing season. Hautke (1957) found that with 2-year-old plants growing in the field in Russia the starch content of the roots increased by a third between harvest time at the end of August and mid-October.

The present experiment has been valuable in showing the general changes in the food reserves of young plants grown for

one year. It has indicated the possible relationship between fluctuations in food storage and changes in the annual growth cycle.

By growing the plants in pots a detailed study of the roots was facilitated but it would be unwise to draw firm comparisons between these plants and those growing in the field. The next stage will be to examine mature plants in the field and to examine the effect of cultural practices, such as stripping and bine cutting, first upon the carbohydrate build up, and second upon current and subsequent yields.

The present experiment indicates strongly that young newly-planted hops should be allowed to carry as much healthy leaf as possible in their first year in the field and that, where possible, hand-picking should be practised leaving the plant with leaves intact, to continue storage build-up until the shoot dies naturally. In this way, plants will be brought to full yielding capacity as quickly as possible.

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OVERWINTERING OF HOP DOWNY MILDEW
PSEUDOPERONOSPORA HUMULI (MIY. AND
TAK.) WILSON

J. R. COLEY-SMITH

SUMMARY

An account is given of experiments which suggest that *Pseudoperonospora humuli* can overwinter, in infected hop rootstocks, in the form of mycelium, and that buds can be infected as a result of mycelium growing up into them via the cushion of tissue on which they are formed. The experiments also suggest that oospores, at least in the season following their formation, are of little or no importance in the formation of systemically infected shoots in spring.

Suggestions are given for control of the basal spike form of downy mildew.

INTRODUCTION

Although Downy Mildew disease of hops has been known in this country for over thirty years the exact means by which the fungus causing it overwinters is still unknown (Coley-Smith, 1959).

The first signs of the disease in any season are systemically infected shoots (basal spikes) which arise from the crown. Spores from primary basal spikes, dispersed by wind or by rain splashes, bring about secondary infections and so initiate a chain of events which may ultimately result in infected cones.

At the beginning of the present work it was realized that there are several possible ways by which primary basal spikes could be formed. These include:

- (i) By germination of oospores of *P. humuli* in spring producing zoospores which infect the shoots as they grow up through the soil.
- (ii) By infection of buds on the rootstock in autumn by zoospores washed down from the aerial regions, the resulting mycelium remaining dormant in the buds until the following spring.
- (iii) By the existence of a perennial mycelium of the Downy Mildew fungus in rootstocks of hops from which the mycelium invades buds and developing shoots.

This paper describes recent work on overwintering of hop Downy Mildew disease.

MATERIALS AND METHODS

Plants of the variety Eastwell Golding were used in all the experiments described in this paper. Except where otherwise stated they were grown in an unheated glasshouse from two-node soft-wood cuttings rooted in a mist propagation unit in July (Williams and Sykes, 1959).

Suspensions of zoospores of *P. humuli* were prepared from sporangia produced on artificially infected pot plants. The sporangia were washed off the leaves with distilled water and standardized at 20,000 per ml. by means of haemocytometer counts followed by the appropriate dilution. Suspensions were always used just after zoospore emergence.

Material for permanent sections was fixed in formalin-acetic-alcohol, dehydrated by the tertiary butyl alcohol method of Johansen (1940) and embedded in B.D.H. paraffin wax (M.P. 52° C.) with ceresin. Before sectioning woody material was placed in a softening solution (Alcorn and Ark, 1953) for 3-7 days at 37° C.

Several staining methods have been investigated. By far the best of these was a modification of the method of Fraymouth (1956). In this method material was stained for five or more minutes in 1 per cent. aqueous B.D.H. resorcin blue, rinsed in water and washed for 2-4 seconds in each of two changes of absolute ethanol, cleared in xylene and mounted in neutral Canada balsam. Fungal hyphae and haustoria are stained bright blue whilst the host tissues become either a pale brown colour or are not stained. This procedure works equally well with woody or non-woody tissues and is suitable for sections of both wax-embedded and fresh material.

RESULTS

Experiment 1

In the first experiment basal spike production by healthy pot plants was compared with that from strap cuttings known to contain the Downy Mildew fungus. The cuttings were taken from field plants in early March, about three weeks before the appearance of the disease. They were surface sterilized in a 1 in 40 suspension of calcium hypochlorite for five minutes and washed thoroughly

before use. Four treatments, each involving thirty plants of each type, were imposed:

- (i) Untreated controls grown in John Innes compost.
- (ii) Plants grown as above and inoculated ten days later by pouring 10 ml. zoospore suspension over the surface of each pot. At the time of inoculation the shoots were just breaking through the soil surface.
- (iii) Inoculated with oospores from naturally infected cones collected in the previous autumn and over-wintered outside. Twenty bracts or bracteoles containing oospores were placed just below the compost surface in each pot.
- (iv) Potted in compost with a 1 in. layer of field soil spread over the surface. This soil was taken from around diseased plants in a garden with a severe Downy Mildew record.

The plants were grown in a heated glasshouse (minimum temperature 60° F.) and basal spike numbers were recorded for 40 days. As soon as sporulation was observed the appropriate plants were removed from the glasshouse to minimize secondary infections. Results of the experiment are summarized in Table 1.

TABLE 1
BASAL SPIKE PRODUCTION BY DISEASED STRAP CUTTINGS AND HEALTHY
POT PLANTS OF EASTWELL GOLDING

Treatment	Cuttings (A) or pot plants (B)	Number of plants (out of 30) with shoots	% plants with shoots which also possessed basal spikes
Control {	A	11	38
	B	30	0
Watered with zoospore suspension {	A	16	56
	B	28	28
Inoculated with oospores {	A	14	60
	B	27	7
Inoculated with field soil {	A	9	38
	B	29	0

Many of the diseased cuttings failed to produce shoots at all and of those that did a large proportion produced basal spikes. These were of the typical primary type seen in the field during the early part of the season. It would be unwise to draw any conclusions

from treatment differences in the case of diseased strap cuttings since the percentages are based on such small numbers. Healthy pot plants produced far fewer basal spikes, except in the case of those treated with zoospore suspension, and of those produced none were of the typical primary type. These results suggested that although the strap cuttings were taken early in the season they either already possessed infected buds or that mycelium grew into the developing buds and shoots from the cutting. It should be mentioned here that numerous methods have been tried for inducing oospore germination in the laboratory, without success.

EXPERIMENT II

Another small experiment was designed to discover whether infection of plants in the autumn would result in basal spike production in the following spring.

The plants were inoculated in mid-September by pouring 20 ml. zoospore suspension on to the soil surface of each pot around the base of the bine. They were kept in an unheated glasshouse during the winter and subsequent growth was observed in the following spring. Results are shown in Table 2.

TABLE 2
BASAL SPIKE PRODUCTION BY EASTWELL GOLDING PLANTS INOCULATED
IN THE PREVIOUS SEPTEMBER WITH ZOOSPORES OF
Pseudoperonospora humuli

Treatment	Number of plants	Number of plants with <i>P. humuli</i> confirmed in rootstock	Number of plants dead	Number of plants with basal spikes in spring
Inoculated with zoospore suspension	15	9	2	4
Uninoculated controls	15	0	0	0

When examined in spring nine of the fifteen plants inoculated were found to have been infected and their rootstocks were in various stages of decay. Two of the nine were dead and four others produced basal spikes.

EXPERIMENT III

In view of these results another experiment was set up in which plants were inoculated as before and sampled at intervals during

the winter to determine the progress of the disease. This was done by sectioning fresh material by hand or with a freezing microtome. Wax embedded buds and shoots were sectioned at intervals of 8–16 μ with a Cambridge Rocking microtome. Five inoculated and five control plants were examined in each sample.

The progress of the disease is shown diagrammatically in Fig. 1. The first signs of infection were discovered a fortnight after inoculation in two of the five sample plants at the base of the current year's shoot and it would appear that the fungus entered the stem at or near soil surface. After entry the fungus grew in both an upward and downward direction and by the middle of October rootstocks were extensively colonized but no infected buds were found although hyphae were present in many of the cushions of tissue from which the buds arose. In the November sample the fungus had invaded almost the entire rootstock and 26 per cent. of the dormant buds were diseased (Table 3). Penetration of

TABLE 3
INFECTION OF BUDS ON ROOTSTOCKS OF EASTWELL GOLDING
INOCULATED WITH ZOOSPORES OF *Pseudoperonospora humuli*

Time after inoculation	% buds containing <i>P. humuli</i>
2 weeks. Early October	0
1 month. Mid-October	0
2 months. November	26
3 months. December	24
4 months. January	41
5 months. February	46
6 months. March	37

the dormant buds was by hyphae passing into them via the cushion of tissue on which they were formed. In the November and later samplings healthy and infected buds were frequently found on the same node. By January the fungus had stopped growing and following this there was no significant increase in the extent of growth in the rootstocks or in the percentage of dormant buds infected. In the March sample it was obvious that most of the buds invaded earlier in the winter were already dead. Thirty rootstocks were left until the end of May but only one of these produced a basal spike. The buds on the other twenty-nine plants were completely rotted. There was evidence, however, that the fungus had started growing again in some of the roots.

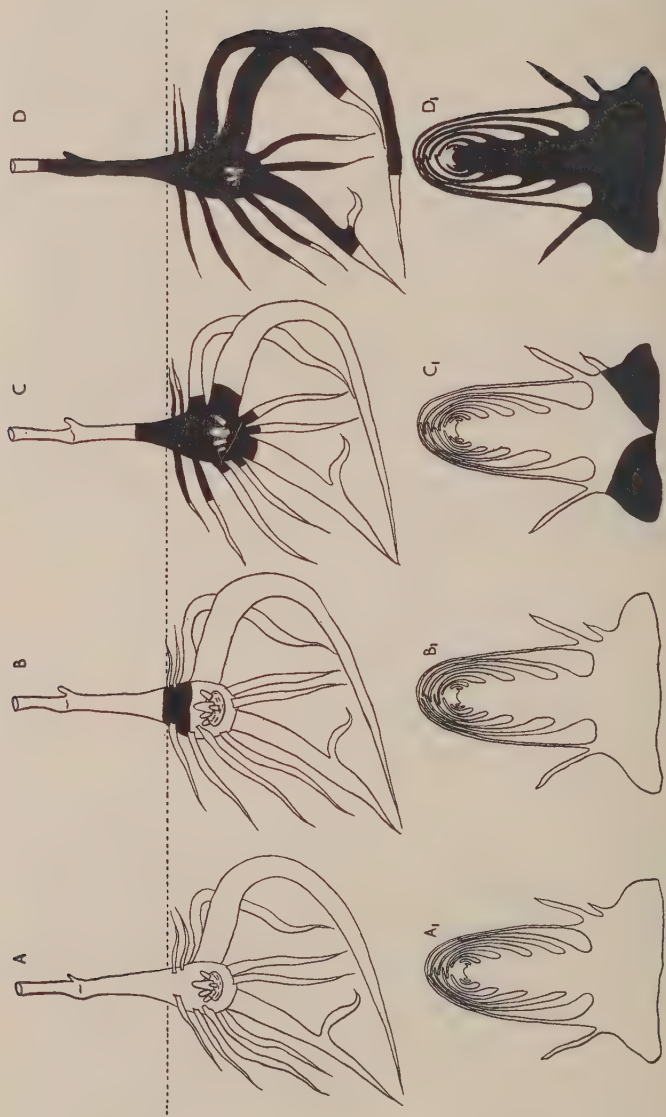


FIG. 1

Growth of *Pseudoperonospora humuli* in artificially infected pot plants of Eastwell Golding. A-D diagrammatic representations of rootstocks, A1-D1 vertical sections through dormant buds. A and A1 one week after inoculation (September), B and B1, two weeks after inoculation (early October), C and C1 one month after inoculation (mid-October), D and D1, two months after inoculation (November). The diseased area is shown in black. The dotted line indicates the soil surface.

A curious phenomenon found in some of the later samplings was the presence of isolated patches of Downy Mildew infection in roots. Whether these were a result of direct penetration of roots by *P. humuli* is not yet known but it is difficult to visualize any other explanation. *P. humuli* has always been considered to enter hops by way of stomata.

This experiment, whilst proving that dormant buds can be infected as a result of fungus passing into them from a diseased rootstock, did not prove conclusively that this results in basal spike formation. The final condition of the rootstocks suggested that the progress of the disease had been more rapid than in the pilot experiment set up in the same manner in the previous year. This may have been due to the high temperatures recorded for a considerable period after the plants were inoculated. The experiment will be repeated with modifications.

DISCUSSION

The evidence presented in this paper, together with the well-known fact that the Downy Mildew fungus can be found in hop rootstocks throughout the year, strongly supports the theory that in this country primary basal spikes arise as a result of infection from overwintering mycelium in the rootstock and that oospores are of less or no significance in this respect. On the continent and in the U.S.A. the current opinion appears to be that primary basal spikes arise as a result of infection by overwintering oospores.

An argument which has been raised against the presence of a systemic perennial mycelium as the cause of basal spikes is that healthy and diseased shoots may arise from the same node. In the present work buds infected by mycelium passing into them from below were frequently found on nodes also possessing healthy buds. In this work dormant buds which were invaded in the autumn died and then rotted. It seems probable that primary basal spikes arise from buds which are invaded by fungus passing into them from the rootstock in spring.

This paper also demonstrates the importance of using healthy planting material. If diseased cuttings are planted the majority do not take and of those that do a large proportion produce basal spikes.

In the past very little has been done to control basal spikes apart from removing them in order to minimize secondary infections. Research in this department is also designed to discover

methods by which primary basal spikes can be controlled. This work has now given sufficient results to enable tentative recommendations to be made.

In the case of hills which are already systemically infected by Downy Mildew disease no curative methods are known by which infection in the hills can be eliminated. The only method by which primary basal spike numbers and rootstock death could be reduced in these cases would be by systematic grubbing and replanting of plants which produce large numbers of basal spikes or which are found to be badly infected when the hills are dressed. This policy is now being carried out in this Department.

In the case of a garden with very little Downy Mildew disease, especially when starting from new planting material, a different policy can now be recommended. This consists of dusting the crown of the hill and the shoots with Bordeaux powder during the growing season. The powder is applied from a sack at the rate of 15-20 lb. per acre per application. The treatment which has proved most effective in reducing systemic infection and basal spike numbers at Wye (details of this work are given on page 27 of this report) consists of dusting the hill three times during the early part of the season (April-June) at approximately three-weekly intervals and thereafter once per month until September. Three early applications without the later ones were also very effective. The first dusting has been carried out when the shoots were 2-4 inches in height. Further trials are being carried out in this Department to obtain more information on this subject.

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PAPER 5.

THE SEED CONTENT OF TRIPLOID HOPS

R. F. FARRAR

SUMMARY

Work carried out at Wye is reviewed. The triploid hops examined, while not seedless, had a much reduced seed content compared with normal diploid commercial varieties. Some aspects of this finding are discussed.

INTRODUCTION

When normal methods of hybridization are used to produce new hop varieties, the heterozygous nature of the species tends to create a very wide range of characters in the seedlings. Frequently the level of commercial quality possessed by the female parent is not attained in any of the female offspring raised.

In an attempt to increase the probability of transmitting the good qualities of selected female parents to progeny raised from them, Dark (1953) introduced the technique of polyploid breeding to Wye in 1950. In this an artificially produced tetraploid form of the female hop variety to be used for breeding was crossed with a normal diploid male with some known quality such as disease resistance. All the seedlings resulting from such a cross could be expected to be triploid, and two-thirds of their inherited characters would have been contributed by the female parent. It was hoped that this bias on the female side would result in the female seedlings bearing a close resemblance to one another and to the selected female parent.

The technique used at Wye to produce tetraploid forms of selected hop varieties, and the early results of analyses of triploid families have been reported by Dark (1953) and Neve and Farrar (1955). The raising of triploid families is now a regular feature of the breeding programme.

Triploids in general look much the same, and grow in much the same way as diploid seedlings, with one notable exception—a reduced seed content. Dark had foreseen this, and triploids came to be loosely referred to as sterile or seedless. There was a fear that seedless cones may fail to “grow-out”, or remain too long in

burr and risk infection from disease. Howard (1904) reported both these occurrences on diploid varieties when pollination was slight or absent. These fears have proved to be groundless; the burr of triploids is affected by pollination and the cones "grow-out" in much the same manner as in diploid varieties. Early observations at Wye indicated that there were occasional seeds in triploid cones and that some appeared sound. In 1955, a series of investigations was started in an attempt to determine the true position of triploid hops with regard to seed content.

INVESTIGATIONS

In the first instance a series of 15 established triploid seedlings of Bullion (Q43) and three Bullion plants growing with them, were selected for examination. Samples of cones were collected, dried, weighed off into 10 gm. lots and all seed picked out by hand. This work, reported by Farrar (1956), showed a significant difference between weights of seed contained in the dried samples from the two groups, the triploids yielding the lower results. Hops are sold by weight, therefore the numbers of seeds need not be considered here. The 15 triploid samples had a mean of 6.9 per cent. seed by weight and ranged from 10.0 per cent. down to 4.0 per cent. The three Bullion samples had a mean of 24.5 per cent., with a very narrow range of 25.9 per cent. down to 23.5 per cent. These results showed three important facts:

- (1) Triploids are not really seedless.
- (2) Triploids have a much lower seed content than diploids.
- (3) Seed content varies from triploid to triploid.

Investigations were extended in 1956 to include the variety Fuggle N and triploids derived from its tetraploid form.

With the Fuggle series, results obtained in 1956—their first year—and the two following years, showed that more seed was set as the hills aged. Table 1 shows the rate of increase of three Fuggle triploids compared with diploid Fuggle. The very low seed content of a triploid in its first year may partly be explained by the fact that it flowers late, after the main pollen flow, and is, therefore, only lightly pollinated. It is probable that this increase ceases after the third year when the hill is established, but there appears to be a seasonal variation, the pattern of which is being investigated.

In 1958, eight of the now established Fuggle triploids were compared with each other and with three Fuggle hills, in the same

TABLE I
SEED CONTENT OF DIPLOID FUGGLE AND TRIPLOID SEEDLINGS OF FUGGLE.

			1956		1957		1958	
			Wt. of sample (gm.)	Wt. of seed %	Wt. of sample (gm.)	Wt. of seed %	Wt. of sample (gm.)	Wt. of seed %
Fuggle	..	..	2.3	16.5	20.0	24.1	20.0	26.0
Triploid A	..	..	10.0	0.4	20.0	5.4	20.0	9.3
B	..	..	7.0	0.6	20.0	5.1	20.0	8.3
C	..	..	7.6	Nil	20.0	0.7	20.0	2.7

In 1956 the Diploid Fuggle was planted as a Bedded Set, and the Triploids were Seedlings in their First Year.

manner as with the Bullion series. The results showed a similar pattern to those obtained from the Bullion investigation, the triploids having a mean of 7.2 per cent. seed by weight ranging from 9.3 per cent. down to 2.7 per cent., and the diploid Fuggle having a mean of 24.5 per cent. with a narrow range of 26.0 per cent. down to 22.8 per cent.

The structure of a triploid cone does not appear to be greatly affected by its lack of seed. The strig can be irregular, nodes supporting seed-bearing bracteoles frequently being more prominent, but the numbers of bracts and bracteoles per cone show no significant difference from the diploid form of the female parent. The results of petal counts made on diploid and polyploid hills of Bullion and Fuggle have been reported by Farrar (1958).

Most of the samples taken for seed content analysis in the work already mentioned were from hills in the plant breeding garden at Wye, where a large number of male hills are maintained. The amount of pollen available when the female hills are in burr must be greater than in normal commercial gardens, and this might be expected to have an effect on the amount of seed. Further, the picking of samples for analysis is carried out very carefully by hand, with negligible loss of seed and the inclusion of no extraneous matter. To determine whether these factors were influencing the results, a series of six commercial samples of Bullion from representative hop-growing areas were analysed and the seed contents were compared with two Bullion samples from Wye. It is clear from the results shown in Table 2 that no real difference is apparent. The results of any seed content assessments made at Wye on triploid varieties can, therefore, be regarded as indicating their probable

TABLE 2
SEED CONTENT OF BULLION FROM COMMERCIAL GROWTHS AND FROM WYE
COLLEGE: 1959 CROP

District	Method of picking	Wt. of seed %
N. Kent	Machine	22.6
N.W. Kent	"	22.6
Mid-Kent	Hand	24.0
Sussex	Machine	24.7
Worcestershire	"	19.5
Worcestershire	"	20.8
Wye	Hand	21.2
Wye	"	22.6

behaviour under commercial conditions, subject to minor seasonal variations.

DISCUSSION

Presumably a triploid hop of fine aroma would be acceptable to the brewing industry for that alone, but is a reduced seed content liable to increase the acceptability of a variety? Brewers of lager beer in this country require hops not only with a very low seed content but also with an aroma of the type found in Continental hops. This fact was recognized, and Neve (1958b) discussed the likelihood of the polyploid breeding programme being able to produce such a hop, and gave an account of the steps being taken at Wye to achieve this.

If it is assumed that triploid hops would be acceptable to brewers, the grower obviously needs to know how a reduced seed content would affect the growing, harvesting and marketing of the crop. Garden management would be the same as for diploid varieties and male hills would still be required. Triploids should prove well suited to machine picking since their cones have been found to shatter less readily than those from diploids. The reasons for this are not clear, but are almost certainly associated with the reduced seed content. Samples from mixed Bullion triploids picked on the machine at Wye in 1958 showed impressive cleanliness and wholeness of the cones. Some variation in suitability for machine picking must be expected, but it appears that triploids pick just as well and probably better than the average commercial hop. In the pocket, lack of seed may mean less weight but more usable hop material and therefore more resin. Neve (1958a) showed

that the mean resin content values for a series of Fuggle triploid families were considerably higher than for the control diploid Fuggle. This suggests that a different scale of valuations may be required for triploids, but further work is needed to clarify the position.

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PAPER 6.

HOP DRYING IN THE 1950's—A REVIEW

P. H. BAILEY

The work of Dr. Burgess during the period 1920-39 (Burgess, 1933, 1940) did much to place the conventional methods of drying on a systematic basis, and thus contributed to a considerable degree to the modernization of drying equipment which has since taken place. His retirement in the early part of the decade under review seems to have coincided with the end of the period of steady improvement of the conventional system, and various developments have taken place in the 1950's which make it uncertain in which direction the main trend in the future will be. One certainty about the decade is that it has seen the swing take place from hand picking to machine picking for most of the hops grown in England, and this has brought new drying problems, some technical, some economic, and some imaginary. The 1950's are no different from any other period in marking the decay of old equipment but the grower who has to renew equipment at the present moment is faced with what may appear to be a confusing choice, as the decade has seen the advocacy of new methods of drying, and continuous driers and multideck kilns have become commercially available.

Research in hop drying, as in agricultural engineering generally, is all intended to benefit the grower in the end. The results of some projects benefit him directly, others—at compound interest, as it were—by making available to the designer technical information necessary for the proper design and development of new methods.

The work of Watson (1954, 1955) at Wye in 1952-54 contributed much that is of direct interest to the grower. A study of the drying of whole hops in comparison with separated strig and petal showed that the separated pieces in fact dry noticeably faster than whole hops and in particular faster than the strigs of whole hops. It was noticed that the presence of broken hops from machine picking in the bed on the drying floor would probably increase resistance to air flow and cause a reduction in air speed, but later investigations by Watson & Pearce showed little difference in pressure. It is perhaps worth noting that investigations by Darling and Thompson

(1956, 1957) on the proportion of petal and seed in comparable machine and hand-picked samples in 1954, 1955, and 1956 showed only a small increase.

Results gained in 1959 from another experiment at Wye by Bailey (see page 60 of this report) showed differences in petal content of 5·3 per cent. in Fuggles and 3·4 per cent. in Bullion between hand and machine picking. These differences do not suggest any great difference in air flow characteristics, and indeed the drying test results obtained in 1956 and 1957 by an N.I.A.E. team with hand-picked Fuggles and machine-picked Bullion and Brewer's Gold, while not directly comparable, at least do not suggest any special difficulty in drying machine-picked hops (Bailey, 1958).

Another paper by Watson (1958) extended the work of Burgess on the effect of air speed and temperature on the quality of dried hops, and showed that while there was a tendency for hops dried slowly with minimum temperatures to receive the best valuation, in fact only small differences in money valuation were made between hops dried with normal commercial methods and hops dried with air speeds up to 60 ft./min. at fairly high temperatures. An interesting feature of this work was that with air speeds high in relation to the depth of loading, it was possible to dry with air at a constant temperature from the outset. Watson commented that the "ultra-rapid" conditions of drying could only find application in kilns using some system of air re-circulation, otherwise the cost of fuel per cwt. of hops dried would be excessive.

Work in the United States in 1953-1956 by Henderson (1958) at the California Agricultural Experiment Station showed that American merchants tended to give the best valuation to samples dried at low temperatures, though the comparisons are open to criticism because only a single miniature kiln was available and the different treatments were given to hops picked on different days. Work by Henderson on drying with humidified air, on the entrainment or flotation velocity of individual hops and a bed of hops, and on equilibrium moisture contents is of significance to the drying engineer.

Research by the drier testing team of the National Institute of Agricultural Engineering in the last four seasons has been of two types—measurement of performance of full-scale installations, and investigations of technical problems using the miniature kilns at Wye, with the kind and whole-hearted co-operation of the Hop Department. The 1956 and 1957 work has already been described (Bailey, *loc. cit.*) and the more recent work was largely an extension of

it. A joint experiment with Wye, the Brewing Industry Research Foundation and a well-known brewer-grower, on the recognition of drying damage, with the object of speeding up the detection of unsuitable drying conditions is still in progress. The main indication is confirmation that alpha acids may be the most sensitive of the easily-measured hop constituents to mistreatment in drying. Other work on the miniature kilns has included an investigation of the effect of drying with a high wet bulb temperature, due to humidification of the air, on the quality of hops. This indicates that recirculation of air should be possible in future continuous drier design without devaluation of the hops. A corollary of this result is that, provided the ratio of air speed to depth of bed is high enough to prevent reeking, it should be possible to apply exceptionally high initial temperatures for the first part of the drying period while a substantial amount of water is still present in the petals of the hop. This is confirmed by Watson's results, by Henderson's results in America, and by a single load dried recently at Wye with an initial temperature of 180° F., subsequently reduced to 150° F. to prevent "cooking" the dried hops. It is important to emphasize that these results are chiefly applicable to continuous drier practice, and are not advised for use in conventional kilns. A brief investigation on sulphuring problems in 2-deck kilns produced negative results, which in effect confirmed the formula devised by Burgess (1933) for sulphuring and the fact that it is the sulphur concentration in the *air* that is important: if a 40-poke load of hops is dried with a constant air speed of 45 ft./min., three times the amount of sulphur is required compared with the drying of the same amount of hops at 15 ft./min. Watson (1955) pointed out that in rapid drying conditions some of the hops are nearly dry before the normal time for the action of the sulphur is completed, and that a technique of sulphuring at very low air speed before the commencement of drying proper may be necessary to produce best results. On the other hand, sulphur appears to have very little effect on the actual brewing value of hops, and with an increasing tendency to hop on resin analysis it may be questioned whether further research on sulphuring is a profitable line of enquiry.

A major part of the research carried out by the N.I.A.E. team in 1956-57 was the examination of the performance of conventional 20 ft. square kilns, and a 20 ft. kiln converted to the 2-deck system. Tests were also made of a continuous drier, now obsolete, and of a small continuous grass drier with some experimental modifications for drying hops. Comparable results were obtained

for conventional kilns of old and new design in Belgium by Jacobs and Maton (1958).

The data obtained on the conventional kilns confirmed the formula worked out by Burgess (1933) for calculating drying time, subject to a correction to the air speed. It follows from the form of Burgess's formula that, for a given air speed, drying is more economical with a deeper loading. This may be expressed by the curve of specific evaporation per load for the average conditions of the kilns tested shown in Fig. 1, the individual results being for hand-

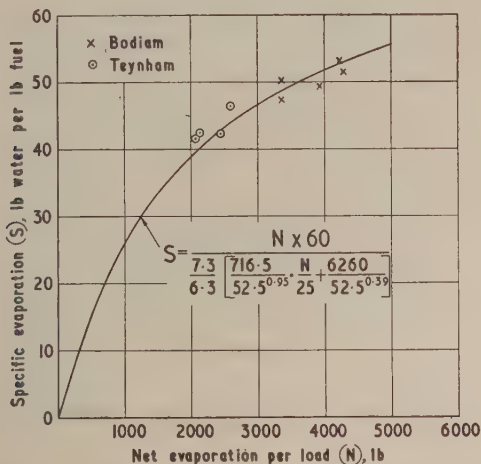


FIG. 1

Comparison of practical results with predictions from modified Burgess formula.

picked Fuggles and for machine-picked Wye varieties. Incidentally, a check on this curve with three different loadings of similar hops, hand-picked Goldings, in 1958 on the 11 ft. kilns at Wye College Oast confirmed the curve shown closely. Translated into practical terms of output, the heavier loading of 5,000 lb.—12.5 lb./sq. ft. of kiln area—calls for a smaller fuel consumption per cwt. than the loading of 9 lb./sq. ft. It will be noted that moisture content of the wet hops has a profound influence on the usage of fuel.

Figs. 2 and 3 examine the reason for this. These show a record of the variation of temperature in the various parts of the kiln—ambient, hot air at entry, and exhaust. Reflected underneath is the

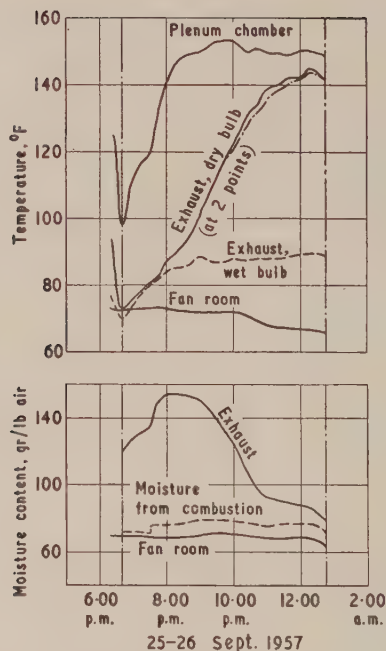


FIG. 2

Variation of temperature and air moisture contents with progress of drying—lighter loading.

record of the moisture content of the *air* at entry and at exit. The distance between the two lines is a measure of the amount of water being evaporated at any time, and the area of the moisture diagram represents the total amount of water in the load.

Fig. 2 represents a comparatively light load: for a short time what the drying engineer calls “constant rate” drying takes place, with water freely available to the limit of the carrying capacity of the air. As the hops become drier, the air is progressively less saturated and heat is wasted as the exhaust temperature rises. If the loading is increased (Fig. 3) the proportion of drying time taking place in the constant rate period is increased, and drying is more economical. There are two limits to increasing load. One is met at a depth of about 0.8 inches per ft./min. air speed, as pointed out by Burgess, as beyond this depth difficulty is experienced in fitting in two loads

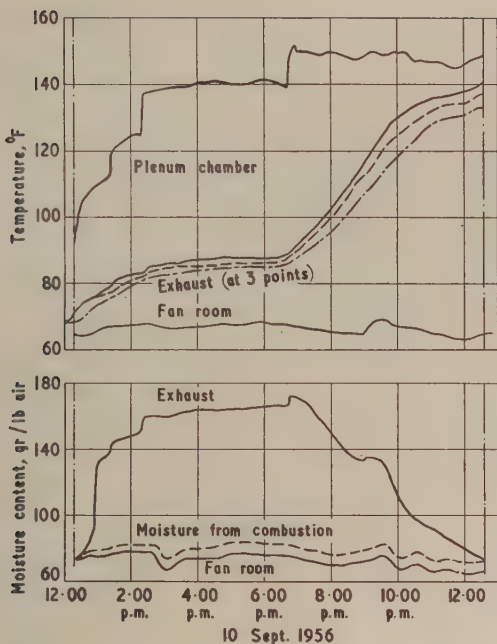


FIG. 3

Variation of temperature and air moisture contents with progress of drying—heavier loading.

a day—but it is a corollary that much less than this depth in relation to the air speed means that the kiln space is not fully utilized. Increase of air speed, and fuel, means that heavier loadings can be used and the utilization of the capital investment in a given area of kiln space improved. However, the second limit to the depth of the hop layer operates eventually, and this is the sheer physical problem of loading evenly to a depth of much more than 30 inches.

The 2-deck kiln provides a solution to further increase in effective depth, coupled with a potential saving in fuel. Two comparatively shallow layers of hops are dried one above the other, and as the used drying air is always exhausted from comparatively wet hops, the wastage of heat is reduced, and more important, the wastage of drying potential is reduced.

There appear to be two divergent possibilities for making use of the increased output per sq. ft. of kiln floor made possible by the use of these methods. One is to obtain increased output from a given kiln area at the minimum cost by maintaining the traditional day and night work (or conversely to maintain a given output from less floor space than previously, this perhaps saving rebuilding costs). One point to be noted is that about the same labour requirement per unit of dried hops is required with a 2-deck kiln. Thus if output is increased, and oast staff is not, the daily output per man is increased; as the work is more continuous in nature than with a conventional kiln, this is liable to prove a strain.

An alternative method of working is to use the extra output potential of the original floor area to eliminate night work. This solution has appealed to several growers who have to rely on their own regular staff. Unfortunately, the full potential fuel economy cannot be realized if a 2-deck kiln is shut down daily, for several reasons of which the most important is that a part of each day's drying consists of a single layer of no great depth. Table 1 illustrates

TABLE 1
PERFORMANCE OF 20 FT. SQUARE KILNS DRYING HOPS
FROM 80 PER CENT. TO 7 PER CENT.

	Conventional kiln 2 loads/day		2 deck kiln	
			Day and Night	3 loads/ day
Loading (lb.)	3,600	5,000	2,400	2,400
Utilization factor (%)	71	87	100	41
Spec. evaporation (lb./gal.)	46	51	64	48
Output of dried hops/day (cwt.)	13	19	33	13
<i>Per cwt. of dried hops:</i>				
Gas oil (gal.)	9.0	7.9	6.7	8.9
Approx. direct labour (man-min.)	60	60	50	50

this point, with a comparison of the conventional 20 ft. square kiln at two different loadings with the 20 ft. square 2-deck kiln worked continuously and worked for three loads per day.

No results are given for continuous driers, as those that have been published relate to non-standard machines. At first sight the continuous drier appears to be the ideal solution to the problem of drying hops coming from a picking machine. There are, however, some difficulties, and the most important is revealed in the word "continuous". Continuous driers in industry really are continuous,

many of them working day and night. On the farm, continuous grain or grass driers work for many hours without a break; but hop picking machines are not worked night and day. They are stopped more than half of each 24 hours, and suffer a number of incidental stops during the daytime—for lunch, tea-breaks, and picking machine breakdowns. With the maximum hot air temperature of about 150° F. which can be applied to hops for most of their drying cycle for reasons of quality, the minimum time they can be in the drier is about four hours, and the total time may well be more than this. It follows that with the various lengths of all the stops which may take place, and the major one each night, there is a problem of control to be overcome. This calls for the development of a new skill by the operator—or possibly for a computer to programme the drying machine and make minor adjustments in accordance with the properties of the dried hops.

A solution to the problem of the control of the continuous drier which appeals to the engineer and perhaps the economist is all-night harvesting. With possible future picking machines needing a minimum of intervention, working 24 hours a day, a truly continuous stream of hops would be maintained and the capital investment for a given output in both picker and drier would be reduced. But as with the deep loads and 2-deck kilns, realism compels the view that the real attraction to the average grower of the continuous drying machine lies in the abolition of night work, and the fact that the day work remaining in this method of drying is the least arduous of any so far devised. As one experienced drier said when asked what he thought of continuous drying machines, “they’ve got to come”. With them will have to come a new skill, or else fairly complicated control equipment.

In the meanwhile, the apparent confusion of different methods available to the grower for the 1960’s will in most cases resolve itself with an examination of the special needs and circumstances of each case, and research will continue with the object of increasing the practicability of the already practical advanced methods of drying, and investigating possible new approaches.

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APPENDIX I

THE CHALLENGE CUPS FOR THE NEW VARIETIES OF HOPS

F. H. BEARD

THE Sixteenth annual exhibition of New Varieties of Hops was held, under the auspices of the Institute of Brewing, at 15 Southwark Street, London, S.E.1, on November 24th and 25th, 1959. As in previous years the show was organized by Messrs. Wigan, Richardson & Co. In addition to the competition entries two new methods of pressing hops, the "Ballot" and the rectangular bale were shown in comparison with the usual pocket. Samples of hops from the three packages were shown with information on the merits and demerits of the two methods.

Three challenge cups are competed for as follows:

(1) The Brewers' Cup, for hops intended as substitutes for American hops; this cup was presented in 1944 by Messrs. Barclay, Perkins; Messrs. Guinness and Messrs. Whitbread.

(2) The Growers' Cup, for hops intended to augment English commercial varieties; this cup was presented in 1946 by the Association of Growers of New Varieties of Hops.

(3) The Hop Merchants' Association Cup; presented in 1949 by this Association for new varieties certified as showing tolerance to *Verticillium wilt*.

The judges were Messrs. D. G. LeMay, M. Jackson, and A. E. Quin, with Colonel F. N. Richardson acting as Chairman.

There was a record entry of 109 samples, twenty-three more than the previous record in 1957. Seventy growers competed, fourteen more than in 1957. The general level of exhibits was very good, and analyses were better than in recent years, the improvements being most marked in the mean levels.

A list of entries together with the analyses carried out at Wye College by Mr. E. W. Weston, is given below in Tables 1-3.

The Brewers' Cup (Table 1) was won by Mr. W. H. Hoad with a sample of Bullion with an analysis of 9.99 per cent. alpha acids and 8.94 per cent. beta resins. This was the highest analysis of any

TABLE 1
ENTRIES FOR BREWERS' CHALLENGE CUP, 1959

Variety and Grower	Parish	Hops moisture-free	
		alpha acids %	beta fraction %
<i>Bullion (Q43)</i>			
*W. H. Hoad	Hawkhurst, Kent	9.99	8.94
W. Hukins	Tenterden, Kent	9.76	8.58
J. F. Bomford Ltd.	Fladbury, Worcs.	9.62	10.25
J. A. Worley	Chart Sutton, Kent	9.51	8.72
E. M. Gorst	Brenchley, Kent	9.48	8.51
G. Nott & Co. Ltd.	Eardiston, Worcs.	9.37	7.43
W. Rogers & Son	Horton Kirby, Kent	9.15	7.62
W. Rogers & Son	Horton Kirby, Kent	8.97	8.14
R. K. Barr Ltd.	Horsmonden, Kent	8.85	8.98
J. Dinnis & Sons	Shoreham, Kent	8.84	9.32
Furnace Farm Ltd.	Lamberhurst, Kent	8.82	11.24
T. D. & H. Harris Ltd.	Tonbridge, Kent	8.77	7.86
Wm. Alexander Ltd.	Shoreham, Kent	8.75	9.11
Tassell Bros.	Ulcombe, Kent	8.71	7.95
John Turner	Kings Pyon, Hereford	8.69	8.80
Guinness Hop Farms Ltd.	Bodiam, Sussex	8.45	8.73
R. D. Wickham	Brenchley, Kent	8.45	7.60
Morphett Bros.	Nettlestead, Kent	8.34	8.39
J. Nott	Kyewood, Worcs.	7.95	10.84
Ashdown Farm Ltd.	Horsmonden, Kent	7.91	7.83
B. P. Tompsett	Yalding, Kent	7.71	7.60
Guinness Hop Farms Ltd.	Teynham, Kent	7.70	10.72
T. E. Wimshurst	Brenchley, Kent	7.63	7.07
Morphett Bros.	Nettlestead, Kent	6.98	8.69
Guinness Hop Farms Ltd.	Braces Leigh, Worcs.	6.91	8.11
<i>Brewer's Gold (C9a)</i>			
R. D. Wickham	Brenchley, Kent	9.39	9.77
Guinness Hop Farms Ltd.	Teynham, Kent	8.17	7.82
Kennington Hall Farms	Wye, Kent	8.05	6.34
E. L. Worsfold	Sutton Valence, Kent	6.79	8.55
<i>Pride of Kent (170a)</i>			
Tassell Bros.	Ulcombe, Kent	8.90	7.44
Tassell Bros.	Ulcombe, Kent	8.26	8.91
Tassell Bros.	Marden, Kent	8.22	6.41
<i>College Cluster (N15 bis)</i>			
Guinness Hop Farms Ltd.	Bodiam, Sussex	7.14	5.56
Guinness Hop Farms Ltd.	Teynham, Kent	4.92	4.64
<i>Malling Midseason (BB28)</i>			
J. F. Bomford Ltd.	Fladbury, Worcs.	6.98	10.52

* Winner of Cup.

TABLE 2
ENTRIES FOR GROWERS' CHALLENGE CUP, 1959

Variety and Grower	Parish	Hops moisture free	
		alpha acid %	beta resins %
<i>Northern Brewer</i> (WFB135)			
J. Nott	Kyrewood, Worcs.	9.95	7.32
† Courage & Barclay Ltd. ..	Hunton, Kent	9.92	7.57
† W. Rogers & Son	Horton Kirby, Kent	9.49	6.66
W. H. Hoad	Hawkhurst, Kent	9.36	8.57
Exors. R. D. Batchelor ..	Gillingham, Kent	9.33	6.88
Whitbread & Co. Ltd. ..	Yalding, Kent	9.27	7.16
V. H. Millen & Sons	High Halden, Kent	9.10	7.72
† A. & K. J. Amos	Wye, Kent	9.05	7.47
Morphett Bros	Nettlestead, Kent	8.98	8.18
H. Veal & Son	Capel, Kent	8.93	7.28
J. F. Bomford Ltd.	Fladbury, Worcs.	8.88	6.55
E. B. Walker & Co.	Martley, Worcs.	8.76	8.31
Morphett Bros.	Nettlestead, Kent	8.66	8.77
J. & P. Day Ltd.	West Farleigh, Kent	8.65	7.61
E. E. Taylor & Son	Kingsdown, Kent	8.62	6.04
Ashdown Farm Ltd.	Horsmonden, Kent	8.55	7.54
† G. Nott & Co. Ltd.	Eardiston, Worcs.	8.43	8.62
B. P. Tompsett	Yalding, Kent	8.42	7.79
Wm. Alexander Ltd.	Eynsford, Kent	8.41	7.52
Tassell Bros.	Ulcombe, Kent	8.33	7.06
J. Paine & Sons	East Sutton, Kent	8.15	7.20
L. D. Saunders	Brenchley, Kent	8.12	6.13
T. D. & H. Harris Ltd. ..	Tonbridge, Kent	7.98	7.06
W. H. Hall	Cranbrook, Kent	7.84	6.02
E. L. Worsfold	East Sutton, Kent	7.75	6.63
Stanley J. Day	Tenterden, Kent	7.64	5.88
J. & P. Day Ltd.	West Farleigh, Kent	7.62	7.35
J. A. Worley Ltd.	Chart Sutton, Kent	7.46	6.76
Wm. Skinner & Son	East Sutton, Kent	7.44	5.93
H. Veall, Jnr.	Staplehurst, Kent	7.40	5.98
Guinness Hop Farms Ltd. ..	Bodiam, Sussex	7.39	6.93
Wm. Skinner & Son	East Sutton, Kent	7.29	5.90
T. E. Wimshurst	Brenchley, Kent	6.98	5.92
John Turner	Gold Hill, Hereford	6.20	7.87
<i>Pride of Kent</i> (170a)			
W. Hukins	Tenterden, Kent	8.48	9.21
J. Paine & Sons	East Sutton, Kent	8.30	10.66
J. F. Bomford Ltd.	Fladbury, Worcs.	7.51	8.95
H. Veall, Jnr.	Capel, Kent	7.13	10.08
A. & K. J. Amos	Wye, Kent	7.09	9.24
<i>Early Choice</i> (FF21)			
R. K. Barr Ltd.	Horsmonden, Kent	4.82	9.40
J. F. Bomford Ltd.	Fladbury, Worcs.	4.31	4.45
OF27			
J. Nott	Kyrewood, Worcs.	8.05	8.80
ON78			
* J. F. Bomford Ltd.	Fladbury, Worcs.	7.57	6.48

* Winner of Cup.

† These 4 samples of *Northern Brewer* were very good and had an excellent aroma and the growers are to be congratulated.

TABLE 3
ENTRIES FOR HOP MERCHANTS' ASSOCIATION CUP, 1959

Variety and Grower	Parish	Hops moisture free	
		alpha acids %	beta resins %
<i>Whitbread Golding Variety</i> (1147)			
R. K. Barr Ltd.	Horsmonden, Kent	7.15	4.67
*Whitbread & Co. Ltd.	Yalding, Kent	6.60	5.41
C. E. & W. S. Millson	Goudhurst, Kent	6.59	6.22
G. A. & S. G. Calcutt	Goudhurst, Kent	6.56	4.72
Whitbread & Co. Ltd.	Yalding, Kent	6.55	4.63
J. & P. Day Ltd.	West Farleigh, Kent	6.54	5.44
C. E. & W. S. Millson	Goudhurst, Kent	6.48	5.61
C. M. Fox Ltd.	Yalding, Kent	6.42	5.71
J. & P. Day Ltd.	West Farleigh, Kent	6.33	4.88
L. D. Saunders	Brenchley, Kent	6.14	5.07
T. D. & H. Harris Ltd.	Tonbridge, Kent	6.01	4.96
J. A. Worley	Yalding, Kent	5.72	6.06
James Day	Yalding, Kent	5.72	4.66
D. H. J. Britcher	Marden, Kent	5.60	5.03
Courage & Barclay Ltd.	Hunton, Kent	5.59	5.05
<i>Bramling Cross</i> (OT48)			
J. & P. Day Ltd.	West Farleigh, Kent	7.37	6.28
†D. H. J. Britcher	Marden, Kent	7.33	5.23
C. E. & W. S. Millson	Goudhurst, Kent	6.88	5.48
C. E. & W. S. Millson	Goudhurst, Kent	6.67	5.39
J. & P. Day Ltd.	West Farleigh, Kent	6.40	5.78
D. H. J. Britcher	Marden, Kent	6.37	3.92
†James Day	Yalding, Kent	6.16	5.70
J. A. Worley	Yalding, Kent	6.00	5.49
<i>Keyworth's Midseason</i> (OR55)			
J. & P. Day Ltd.	West Farleigh, Kent	7.15	6.64
T. D. & H. Harris Ltd.	Tonbridge, Kent	7.07	4.93
J. & P. Day Ltd.	West Farleigh, Kent	7.02	6.19
Guinness Hop Farms Ltd.	Bodiam, Sussex	6.75	5.27
<i>Density</i> (D1)			
D. H. J. Britcher	Marden, Kent	6.53	6.07
<i>Defender</i> (D3)			
Whitbread & Co. Ltd.	Yalding, Kent	6.39	5.42
<i>Janus</i> (J2)			
Whitbread & Co. Ltd.	Yalding, Kent	4.33	5.56
<i>OZ97a</i>			
T. D. & H. Harris Ltd.	Tonbridge, Kent	6.65	8.45

* Winner of cup.

† These samples were of first-class quality having a pleasant but American aroma.

variety exhibited. As in 1958, no second or third placings were made in this class. The Brewers' Cup has now been won for fifteen consecutive years with a sample of Bullion. Only in the first year (1944) was it won with a sample of Brewer's Gold. In 1944 there were 10 samples of Brewer's Gold and 4 of Bullion; in 1959 there were 4 samples of Brewer's Gold and 25 of Bullion, reflecting the change in popularity both with growers and brewers over this period.

The Growers' Cup (Table 2) was, as a year ago, won by Messrs. J. F. Bomford Ltd., but this time with a sample of the unnamed and little grown variety ON78. The sample had an analysis of 7.57 per cent. alpha acid and 6.48 per cent. beta resins. This figure is considerably lower than that of many samples of Northern Brewer. Once again the relatively low importance of P.V. in this class is stressed. In the judges' opinion four samples of Northern Brewer grown by Messrs. Courage & Barclay, Messrs. W. Rogers & Son, Messrs. A. & K. J. Amos and Messrs. G. Nott & Co. Ltd., were very good and had an excellent aroma, and the growers are to be congratulated.

As in 1958 the Hop Merchants' Association Cup was won by Messrs. Whitbread & Co., Ltd., with a sample of Whitbread Golding Variety. The judges considered that samples of Bramling Cross from Mr. D. H. J. Britcher and Mr. James Day were of first quality, having a pleasant but American aroma. This class is still very much a contest between the above two varieties. As in the previous year there were only single entries of the new East Malling varieties and OZ79. The number of Whitbread Golding Variety entries had risen from 11 to 15 and Bramling Cross entries had fallen from 9 to 8.

APPENDIX II

THE 1959 HOP SEASON

WEST MIDLAND REGION

G. P. CHATER

(Hops Advisory Officer, West Midland Region, N.A.A.S.)

THE reduction in the estimated market demand to 83 per cent. of the basic quota was larger than had been expected. The acreage in 1959 in the West Midlands was $5\frac{1}{2}$ per cent. less than in 1958. Many areas severely affected by disease, especially Nettlehead, were grubbed out. There were also many other areas in which most of the stocks had decayed during the winter due to the water-logged conditions of the previous year.

The "Puddling" received by most yards during 1958 and the absence of good winter frosts made spring cultivations difficult to carry out. The low quota, following two heavy crops, encouraged growers to make false economies in the use of their early manures. As the dry weather continued, almost unbroken, throughout the spring into the early summer, growth became slower and various remedies were tried to stimulate backward yards. Spraying with various types of foliar nutrients was tried but the results were conflicting and it was seldom that any difference between sprayed and unsprayed hops could be seen at the time they were picked. Irrigation was used on a number of farms but accurate comparisons between irrigated and non-irrigated hops were difficult to obtain. In one case the difference in yield as assessed by eye appeared to be at least 2 cwt. per acre (dry hops) in favour of the irrigated hops. The actual difference, when weighed, was less than 50 lb. per acre.

Goldings were favoured by the hot, dry summer and excellent crops of good quality were grown with little trouble. Fuggles were not so favoured and many yards lacked their normal vigour with the result that some yields were the lowest for several years. The more vigorous Fuggle yards were generally those where the stronger bine had been trained early. This agrees with the results from the hop experiments at Rosemaund Experimental Husbandry Farm, Hereford, which have been published recently.

The mechanical spinner, which removes the soil covering the stocks, properly handled, gave very satisfactory results. There was no difference in the growth between stocks treated in the traditional manner and those cut after the spinner had removed the surrounding soil.

PESTS AND DISEASES

The Aphis attack was very heavy and started much earlier than usual. Hops were heavily infested during the third week in May and continued to be attacked until the end of June. With a few exceptions, damage to growth was negligible. The aerial systemic insecticides appeared to have a relatively shorter life in the early part of the season than in previous years. In some yards there was a late build up but the crops were not damaged.

The Hop Red Spider, although favoured by the season, was controlled by the systemic insecticides.

The Hop Root Weevil was favoured by the dry summer. Little damage was seen in the spring of 1959 but in 1960 heavy infestation and damage has been observed. Aldrin has continued to control this pest where it has been applied properly.

Downy mildew basal spikes were very common in many yards during the early part of the season. As the dry weather continued, all signs of infection disappeared, and the crop remained free until it was picked.

Powdery mildew was observed in many yards but normal control measures usually prevented any serious damage to the crop. A few cases, especially in Northern Brewer, were not controlled in spite of many applications of sulphur and karathane. High volume washing, particularly with karathane, appears to give the best control, but should be carried out before the foliage has become too dense for it to be completely covered.

The spread of Nettlehead in the early part of the season caused considerable anxiety. Bullion, a variety thought to be resistant to this disease, has been attacked in some places.

Split Leaf Blotch was very prevalent and was the cause of lowered yields in many yards.

Mosaic was less severe than usual, especially in the Teme Valley.

PICKING AND DRYING

The weather remained dry throughout the picking season. The hops did not ripen any earlier than usual and many yards

of Fuggles were affected by "Green Streaks" of petals down the hop, instead of the well-known "Green Heel". The bines were very suitable for machine picking and it was seldom that any machine was pushed to full capacity. The standard of picking was, therefore, generally better than it had been in the two previous seasons. On very hot days the hops were often "wilted" by the time they reached the machine and so were more difficult to pick. Dust in the machine shed was also troublesome and the application of water in a fine mist was often used at the plucker banks to overcome these problems. While the dust was satisfactorily controlled, this method did little to improve the quality of picking. A more successful method of overcoming the "wilting" was to spray water (high volume) on the bines in the yard $\frac{1}{2}$ -1 hour before they were cut.

New oil heaters with higher air speeds continue to be installed. The full benefit from such increased air speeds is not always obtained because the size of the outlet has not been correspondingly increased.

APPENDIX III

THE 1959 HOP SEASON

SOUTH-EASTERN REGION

CATHERINE L. JARY, B.Sc., HORT.

(Hops Advisory Officer, South-Eastern Region, N.A.A.S.)

THE year 1959 will be remembered for the long, hot, dry summer, but at the beginning of the year, growing conditions were very good. Following an open winter, growth started early and the hops were considerably more forward than usual up to about the end of June. After that, the effects of the drought began to be felt; lateral development was rather stunted and the hops stayed in burr for a long time. At this point is looked as though the quota of $84\frac{1}{2}$ per cent. could not possibly be achieved, especially since about 400 acres had been grubbed, but after rain at the end of July, the picture altered completely.

The hops grew out well and although they stayed very green, the moisture content was lower than usual and the final dry weight considerably higher than appeared from a visual estimate of the crop. Contrary to expectations, the quota was actually exceeded. The drought showed up a number of weaknesses, in particular, badly drained land, especially that which had suffered from water-logging in the previous summer, and hops which had been cut early for machine picking in the previous year.

Irrigation was carried out by several growers and considerable advantage was claimed. Certainly if it did not pay in 1959, it never will, but response is likely to vary with soil conditions in the case of a perennial deep-rooted crop such as hops. Another practice which attracted attention during the year was straw "mulching". It is not true mulching, but the straw (usually 3-4 tons per acre) is worked into the top soil by rotovator and additional nitrogen added at the rate of 2 cwt. of sulphate of ammonia or its equivalent per ton of straw. This method of management appears very promising and is likely to increase.

PESTS AND DISEASES

The year's troubles started, as always, with the basal spikes of downy mildew and this was followed in mid-June by a very bad outbreak of terminal and lateral spikes. Such secondary attacks are more spasmodic than the original spikes and appear to depend on weather conditions. In this case they appeared to be started by a short rainy period in mid-May and subsequently built-up during a long sequence of fine days with heavy dews at night. Many growers with the new varieties, which are subject to this form of infection were caught unawares and lost a lot of bine. The outbreak stopped suddenly in the second week of July, following a period with temperatures well over 80° for several days, and there was no recurrence. The final crop was virtually free from downy mildew.

Powdery mildew (mould) was present throughout the season, but was generally well controlled, except in the case of especially susceptible varieties, such as Northern Brewer.

Progressive *Verticillium* wilt continued to spread, but there was virtually no Fluctuating wilt to complicate the picture, and no repetition of the apparent breakdown of wilt-tolerant varieties which occurred in 1958. A sinister feature was the discovery of five new cases of Progressive wilt, in East and North Kent, and one recurrence on a farm already scheduled. The total number of cases which have occurred in this special area is now 15, but in all the older outbreaks, with the one exception mentioned, the disease appears to have been eradicated, following the grubbing of substantial areas of hops. In the South-East Region as a whole, 275 farms are now scheduled as infected (21 of which are no longer growing hops) and the total acreage of infected land is about 5,000 of which 210 acres are not now growing hops and nearly 1,500 acres are under wilt-tolerant varieties. In view of the amount of wilt-infected land in Mid and Weald of Kent and the large amount of traffic which occurs all over the county from farm to farm, not necessarily concerned with hops, there must be an increasing danger that Wilt will be taken to East Kent. If the area is to be kept clean, hop growers must, therefore maintain unceasing vigilance and must report any suspected cases immediately, so that the disease can be eradicated by the minimum of grubbing before it has got very far.

The position regarding wilt-tolerant varieties has been eased by the widespread acceptance in the trade of Whitbread Golding Variety, while growers can now look forward to a choice of Density, Defender and Janus in the immediate future, and in the longer term,

the new varieties from the Wye College/East Malling joint scheme.

Aphis attack was severe, and under the very hot dry conditions the systemic insecticides did not last as long as usual, but their efficiency is still such that this once greatest scourge of hop-growing is no longer a problem.

PICKING AND DRYING

Hop-picking began early and was over in record time. In spite of their greenness, the hops were really ripe and Fuggle shattered from the start when machine picked. In most of the Region, the whole crop was picked but in East Kent quite a lot of hops were surplus and this allowed machine pickers to waste the loose petal.

There are now about 260 machines picking about 7,000 acres, approximately half the total in the South-East. The English machines appear to have settled down in their present form, but one Belgian machine was imported and demonstrated on a farm in mid-Kent where it attracted many visitors. It occupies an appreciably smaller space than English machines of comparable output and could be accommodated in ordinary farm buildings. Its performance relative to the English machine could not really be assessed by observation, but the bine feeding and unloading mechanism would seem to require modification to suit our conditions.

APPENDIX IV

REPORT ON EXPERIMENTAL WORK ON HOPS AT ROSEMAUND: A REVIEW

H. S. DARLING

A RECENT event of major importance for English hop growers was the appearance in 1959 of the "Report on Experimental Work on Hops" written by Messrs. E. L. Jones and N. Moss of Rosemaund Experimental Husbandry Farm and published in veritype by the Ministry of Agriculture, Fisheries and Food. A short summary was circulated to all registered hop producers with the information that the full 60 page version of the report would be sent on request. Further copies of the full report are available from the Director, Rosemaund Experimental Husbandry Farm, Preston Wynne, Hereford.

Rosemaund is the only centre in England apart from Wye College where official field trials are carried out with hops. Situated in Herefordshire on soils derived from Old Red Sandstone this experiment farm is intended primarily to serve the needs of the West Midlands. While the importance of local conditions should not be minimized, it would be a mistake to assume that the results of the Rosemaund hop experiments are of value only to West Midland growers. The data presented in this excellent report are clearly relevant to hop production in other areas and will repay careful study by growers and research workers in the South-east.

This report is mainly concerned with a series of six replicated trials carried out in Slade Hopyard at Rosemaund on a soil of the Bromyard Series using wirework 14 ft. 6 in. (4.35 metres) high. Five of the trials use the variety clonal Fuggle N of which the stocks were planted as layer cuts or bedded setts in March, 1952. The sixth hop experiment is a trial of the New (Wye) Varieties planted originally in October, 1952. These trials were discussed in some detail in a progress report published five years ago (Jones, Cheal and Thompson, 1955) which described the treatments applied in each case but gave no yield data. The present report summarizes yield and other data for the five year period 1954-58 inclusive.

The Rosemaund hop experiments owe much in concept and design to Dr. A. H. Burgess, formerly Adviser on Hops to the Government and late Head of the Department of Hop Research at Wye College, to Mr. G. P. Chater, Hops Advisory Officer, N.A.A.S., West Midland Region and to Dr. D. A. Boyd of the Department of Statistics, Rothamsted Experimental Station. The management and running of the experiments are the responsibility of the station staff at Rosemaund who receive guidance in this work from the Hops Working Party, a scientific advisory committee set up in 1954 for this purpose by the Ministry of Agriculture, Fisheries and Food. Wye College is represented on this Working Party thus ensuring efficient co-ordination of research effort.

Of the six trials for which results are summarized, the first to be discussed is the Row and Square Experiment. Here hops spaced at 3 ft. 6 in. in rows 7 ft. 3 in. apart (1.05×2.15 metres) with Worcester stringing were compared with hops planted at 7 ft. 3 in. by 7 ft. (approximately 2.10 metres square) with umbrella stringing. Both systems gave 3,320 strings per acre; the row plant had 1,660 hills and the square plant 830 hills per acre.

No consistent yield differences have been observed and over five years both treatments averaged 23 cwt. of dried hops per acre. It should be noted that this trial was not a strict comparison of the South-Eastern and West Midland systems of planting. The former, as a rule, has approximately 4,000 strings per acre while normal West Midland work has only 3,000 strings per acre.

The second trial mentioned is the Cultivations Experiment in which hops planted on the square at 6 ft. 6 in. (1.95 metres) were cultivated for different periods during the summer in one direction to a soil depth of 6 in. (15 cm.). No consistent yield differences were observed. Hops cultivated deeply in this way throughout the summer gave the same yield as those which were never cultivated in the summer to a depth greater than 3 in. (7.5 cm.). Over five years the experiment as a whole averaged 22.7 cwt. of dried hops per acre.

The third of the six trials is the Manurial Experiment in which different levels of applied nitrogen, phosphate and potash are under comparison; a magnesium treatment is also included. This trial is not yet complete but results for 1954-58 suggest that annual applications of nitrogen totalling more than 250 lb. N per acre may depress yields. As was to be expected, applications of 250 lb. P_2O_5 per acre have given substantial yield increases over treatments with no phosphate. Applications of up to 200 lb.

K₂O per acre have also increased yields but a higher rate of application has given no further yield response. Applications of magnesium have had no effect, due possibly to high natural levels of this element in the Rosemaund soil. In addition to yield figures, the report also summarizes soil and leaf analysis data, the importance of which is discussed.

The fourth trial is the Dressing and Training Experiment. Here observations on different times of dressing have shown that this operation is best carried out in March. Delay in dressing until mid-April reduced yields on the average by 3 cwt. of dried hops per acre compared with those obtained from treatments dressed earlier in the season. Dressing in November-December and in February gave yields slightly below the March treatment but much greater than from dressing in mid-April. At all times of dressing it was observed that the highest yield was obtained by training the strongest bines in the spring. During 1954-58 the trial as a whole averaged 21 cwt. of dried hops per acre.

The fifth trial mentioned is the Cutting and Stripping Experiment. In this trial, cutting the bines at picking time in September at 5 ft. (1.50 metres) above ground level was compared with leaving the bines uncut until late October. This comparison was combined with studies on stripping off the lateral shoots and main stem leaves from the bines during the summer to heights of up to 5 ft. above ground level. No consistent yield differences were observed.

This negative result may come as a surprise to those with long experience of the effect of cutting the bines for machine picking on subsequent growth and yield. Such growers will be interested to know that the problem is being examined afresh in more detail by an elaborate trial which is described briefly in the closing pages of the report. This trial, known as the Bine-cutting Experiment is laid out in Jubilee Hopyard using the variety clonal Fuggle N grown on the Worcester row system. Treatments in this trial were first applied in September, 1957, but no results were available when the report was written.

The sixth trial in Slade Yard is an observation on some of the "New Varieties" of hops. Fourteen of these varieties are mentioned. All have performed satisfactorily at Rosemaund except John Ford which proved very susceptible to downy mildew and was discarded in 1955-56. Of the remaining varieties, Bullion gave the heaviest yields closely followed by Norton Court Golding; these averaged 27.7 and 27.4 cwt. of dried hops per acre respectively during 1954-58. Northern Brewer also yielded well with an

average of 24·8 cwt. while Early Choice at 24·7 cwt. per acre has done exceptionally well for an early hop. The variety with the lowest yield was Malling Mid-season which averaged 20·2 cwt. of dried hops per acre over the five-year period.

In the report mention is made of the Grassing-down Experiment in Prestons Hopyard which was referred to briefly by Jones *et al.* (1955) in the earlier progress report and which began in 1955. This trial was, unfortunately, lost through Progressive *Verticillium* Wilt in the summer of 1957 when only one year's data were available. The results for 1956 are set out in the report but by themselves are clearly of little value.

The authors rightly emphasize the need for caution in interpreting and applying the data which they have so carefully presented in this report. While the warning merits general approval, experienced growers should have little difficulty in profiting from a thorough study of this publication which deals so competently with a range of controversial yet practical subjects. Those growers who have not yet obtained a copy of the full version of the report would be well advised to do so.

REFERENCE

- JONES, E. L., CHEAL, W. F. and THOMPSON, F. C. (1955). Rosemaund Experimental Husbandry Farm: Hop Experiments. Progress Report I. *Rep. Dep. Hop Res. Wye Coll. for 1954*, 83.

APPENDIX V

NOTES ON RECENT PUBLICATIONS AND DEVELOPMENTS IN HOP RESEARCH

F. C. THOMPSON

IN recent years the Commonwealth Bureau of Horticulture and Plantation Crops has extended its coverage of the technical literature on the growing and processing of hops, so that most scientific papers of importance now receive notice in the Bureau's journal *Horticultural Abstracts*. In consequence, it is considered unnecessary to attempt to duplicate the work of the Bureau and the object of these notes is to draw the attention of readers to recent papers on hop research in England, and to work elsewhere which may have some application to English conditions. The latter is a necessary qualification since much research in other countries can only have local application.

(A) ENGLAND

Since the last "Notes" appeared in the 1957 Annual Report, the following papers have been published.

PUBLICATIONS BY STAFF OF THE DEPARTMENT OF HOP RESEARCH, WYE COLLEGE

(other than in the Departmental Annual Report)

- F. H. BEARD (with MISS C. L. JARY). "New Varieties. Summary of the present position." *Annual Booklet of the Association of Growers of the New Varieties of Hops*, 1958, p. 13; 1959, p. 10.
- R. F. FARRAR. "Techniques of hop propagation." *Ibid.*, 1958, p. 32.
- F. C. THOMPSON. "The effect of some cultural factors on growing hops for the picking machine." *Ibid.*, 1959, p. 39.
- H. S. DARLING. "Hop research at Wye College." *Agriculture*, 1959, **65**, 494.
- R. A. NEVE and E. W. WESTON. "Resin and oil relationships in hops." *J. Inst. Brew.*, 1958, **64**, 247.

Two recently published papers which report a relationship between certain fractions of hop resin and hop oil are discussed.

It is pointed out that the choice of samples is inadequate to justify the conclusions drawn concerning the nature of this relationship. (Author's summary.)

G. A. WATSON. "Miniature experimental hop kilns at Wye College." *Ibid.*, 1958, **64**, 240.

The construction of the six-kiln miniature installation is described and figured. Drying is on goat-hair cloths with a controlled flow of electrically-heated air, provision for sulphuring being made. Results are comparable to those obtained on commercial kilns. (Author's summary.)

G. A. WATSON. "Effect of drying temperature and air-speed on hop quality." *Ibid.*, 1958, **64**, 242.

Experiments on hop drying were carried out at Wye College during 1952-54 in miniature electrically-operated experimental kilns, which on test gave dried samples comparable to those produced by a standard commercial kiln. Hand-picked Fuggle, Golding and Bullion hops were used. The quality of the resulting dried hops was assessed mainly by physical examination (based largely on appearance and aroma) of pressed box samples. Final drying temperatures ranging from 130° to 180° F. were tested at a constant air-speed of 25 ft. per min. No difference in appearance resulted from the different treatments, but quality assessed on aroma decreased with increase in temperature. In some cases "burnt" aromas were recorded in hops dried at 180° F. Trials with a range of temperatures and air-speeds of up to 170° F. and 60 ft. per min., respectively, gave drying times of from 3-12 hr. The resulting samples were very similar in quality, and it was concluded that there can be wide variation in drying time without any major effect on market valuation. These results are discussed in relation to possible developments in the commercial drying of machine-picked hops. (Author's summary.)

F. C. THOMPSON and F. H. BEARD. "Old Varieties of hops." *Wigan Richardson & Co., Hop Report 1959 Season*, p. 6.

RESEARCH AT OTHER CENTRES IN ENGLAND

EAST MALLING RESEARCH STATION

Research on *Verticillium* wilt disease of hops, and on hop virus diseases, continues in the Plant Pathology Department at

East Malling and during the past two years publications by members of staff there have included:

J. F. WILSON. "Density, Defender and Janus: three new wilt tolerant hops." *Rep. E. Malling Res. Sta. for 1958*, p. 110.

Three new wilt-tolerant hop varieties have been released from the first of several breeding projects specifically designed for this purpose.

Density (D1) is a late hop of vigorous growth habit and high yield potential. The cones, although small, are of a compact nature likely to withstand damage by machine picking. The variety is extremely susceptible to Downy Mildew and requires a thorough control programme. In brewing trials it has been found suitable for replacing 25 and 50 per cent. of normal grist, and received some favourable reports when used alone.

Defender (D3) is an early hop of vigorous growth habit and good yield potential. It is of above-average susceptibility to Downy Mildew and requires a thorough control programme. In brewing trials it has been found suitable for replacing 25 and 50 per cent. of normal grist and received some favourable reports when used alone.

Janus (J2) is a mid-season hop of moderate growth vigour and yield potential. The cones are bold and borne in a manner likely to suit machine picking. It is of average susceptibility to Downy Mildew and should require only normal control measures. In brewing trials it was acceptable as a substitute for normal grist at 25, 50 and 100 per cent. replacement, and resin analyses suggest that such substitution may be made on a weight-for-weight basis.

All three varieties are tolerant carriers of hop mosaic virus. (Author's summary.)

J. T. LEGG. "A mild strain of hop mosaic virus." *Ibid.*, p. 116.

Evidence from cross-protection tests indicates that two types of hop mosaic, lethal and mild, are caused by strains of one virus (*Humulus virus 1*, Smith). It is suggested that these two isolates are representatives of two groups of strains, severe and mild, distinguished by the former being lethal to Golding hops. (Author's summary.)

J. T. LEGG and P. J. ORMEROD. "Research on hop virus diseases at East Malling." *Ibid.*, p. 157.

Evidence on the mode of spread of Nettlehead is conflicting: the work reviewed suggests either that the virus is spread by a

mobile insect or mite that only occasionally feeds on hop, or that the virus is soil-borne.

No decisive control measures can be recommended but the removal of affected plants followed by replanting can be of great value in prolonging the economic life of a plantation.

The symptoms of split leaf blotch are described and particular attention is drawn to the 50 per cent. reduction of yield from affected plants of the variety Fuggle. (Authors' summary.)

R. V. HARRIS. "Progress in research on *Verticillium* wilt and virus diseases of hops in 1958." *Ibid.*, p. 165.

A review of items of special interest to hop growers.

P. TALBOYS. "Some mechanisms contributing to *Verticillium*-resistance in the hop root." *Trans. Brit. mycol. Soc.*, 1958, **41**, 227.

P. TALBOYS. "Degradation of cellulose by *Verticillium albo-atrum*." *Ibid.*, 1958, **41**, 242.

P. TALBOYS. "Association of tylosis and hyperplasia of the Xylem with vascular invasion of the hop by *Verticillium albo-atrum*." *Ibid.*, **41**, 249.

The above three papers describe fundamental studies on the behaviour of the *Verticillium* wilt fungus in the hop plant.

NATIONAL INSTITUTE OF AGRICULTURAL ENGINEERING

Further investigations on hop drying have been published by P. H. Bailey.

P. H. BAILEY. "Hop drying investigations. II. Performance of improved kilns and continuous driers." *J. Agric. Eng. Res.*, 1958, **3**, 108.

The economic requirements for improved methods of drying hops are examined. The results of tests on a two-deck kiln, a five-band counterflow continuous drier, and a grass drier temporarily modified for drying hops, are reported. Direct comparison of these drying methods with conventional 20 ft. square kilns is qualified by the varying stages of development of each system. (Author's summary.)

P. H. BAILEY. "Hop drying investigations. III. Some properties of hops relating to the drying process." *Ibid.*, 1958, **3**, 226.

Experiments are described on the effects of wet-bulb temperature on the quality of three hop varieties dried in Wye miniature

kilns. The use of wet-bulb temperatures 8-11° F. higher than normal did not appear to have any marked effect apart from a deterioration in aroma in some cases. Investigations are also reported on the following mechanical properties of hops: (1) bulk density, (2) the entrainment velocity of whole cones and separated bracts, and (3) the resistance of beds of hops to airflow. (Summary from *Horticultural Abstracts*.)

BREWING INDUSTRY RESEARCH FOUNDATION

Work has continued on the chemistry of hop constituents of importance in brewing, with particular emphasis on hop oils, and a number of papers have been published in the period under review. A survey of recent developments has been given by the Director, Dr. A. H. Cook, in the following paper:

A. H. COOK. "The brewing scientist looks at hops." *Annual Booklet of the Association of Growers of the New Varieties of Hops*, 1958, p. 5.

The vast increase in knowledge of the chemistry of the resins and other constituents of the hop important in brewing, which has been achieved in recent years, and in which the B.I.R.F. has played a leading part, cannot be overstressed. The subject is, however, so complex that the practical application of the findings of the organic chemists might seem to be a remote possibility, but in this context the attention of growers is drawn to the following recent review paper which though written by a Danish brewing scientist, is published in English in one of our own journals.

M. MEILGAARD. "Hop analysis, cohumulone factor and bitterness of beer: review and critical evaluation." *J. Inst. Brew.*, 1960, **66**, 35.

The writer emphasizes that simplified procedures must be evolved to make use of recent advances in our knowledge of hop chemistry and goes on to describe a set of such simplified procedures now being used in some European breweries. He considers that copper hops for bittering should be bought primarily on their cost per unit of bittering power and that factors such as variety, appearance, colour and smell are of secondary importance. Where aroma is important (i.e. for dry hopping or late additions to the copper) then the hops should be valued primarily on aroma, which

must still be assessed by hand evaluation until more is known about hop oils.

In the same context the following three papers from the Irish Republic show how laboratory analysis is used to control hopping, in one brewery.

L. E. HUDSON. "Hop evaluation and utilization. I. Hop evaluation. II. Hop utilization. III. The deterioration of hops in storage." *Wallerstein Lab. Commun.*, 1958, **21**, 183; 1958, **21**, 323; 1959, **22**, 89.

The system of hop evaluation adopted in the Guinness Brewery, Dublin, is described. It is stressed that the investigations relate to the brewing of unpasteurized stout, in which the preservative activity of hop resins is of major importance. In the brewing of pasteurized beer, hops are used mainly for their bittering power, but Hudson maintains, as a reasonable assertion, that this is related to preservative value.

Assessments of the preservative value of hops by biological stability tests, on beers from an experimental brewery, have been correlated with a simple, chemical determination of "soft resins content". Over a period of years a number of "soft resins factors" have been evolved which, when used in conjunction with the determination of "soft resins content", enable a satisfactory control of hopping to be achieved with hops of varying ages and different varieties.

Experiments are described in which attempts were made to increase hop utilization. The results obtained were inconclusive since changes in the *iso*-humulone content of the finished beer were not always correlated with changes in biological stability.

Some other publications of interest relating to hop investigations in England include:

INSTITUTE OF BREWING HOPS ADVISORY COMMITTEE. "Institute of Brewing hop trials: 1956 crop." *J. Inst. Brew.*, 1958, **64**, 388.

The wilt-tolerant hops, D1, D3 and J2 were selected for trial from the 1956 crop, and the results confirm those of previous seasons that D1 and D3 are in general acceptable as replacement for Fuggles up to at least 25 per cent. of the normal hop grist, and in many cases up to 50 per cent. replacement. On the other hand, previous results have indicated that J2 was also a hop suitable for

replacement at the 25 per cent. and 50 per cent. level, but this season it was not so readily accepted even at the lower level. It was again evident that this hop has an alpha soft resin content little, if any, higher than Fuggles. OF27, a wilt-sensitive, mosaic-sensitive hop, was also included in this season's trial, but it was not wholly acceptable even at 25 per cent. replacement.

W. G. WARRINER. "1147 and all that." *Annual Booklet of the Association of Growers of the New Varieties of Hops*, 1959, p. 4.

Growers of some of the New Varieties may take heart from this paper, which reviews brewing trials with new varieties of hops, carried out at Fremlin's brewery, Maidstone, Kent. The author states that this particular brewery could use several of the new varieties at up to 50 per cent. of the hop grist.

(B) RESEARCH IN OTHER COUNTRIES

Hop research continues to expand in Europe and in other countries overseas. There are now three technical journals devoted entirely to hops, i.e. *Hopfen Rundschau*, published in the German Federal Republic (West Germany); *Der Hopfenbau*, published in the German Democratic Republic (East Germany); and *Chmelářství* published in Czechoslovakia.

Some papers of interest which have been noted are recorded below under subject headings.

DEVELOPMENT OF RESINS IN THE HOP CONE DURING RIPENING

With the greater awareness of the importance of hop resins in the brewing process, brewing chemists in many countries are showing an increasing interest in the development of resins in the ripening cone. This trend is of some importance to growers, since it may ultimately lead to a more critical definition of the best time for harvesting hops and this may conflict, to some extent, with current practice.

Among recent papers bearing on this subject, are the following:

B. D. HARTONG and L. ISEBAERT. "The conductometric determination of alpha acids in green hops on the hop farm." *Wallerstein Lab. Commun.*, 1959, **22**, 17.

This paper reports analyses made at harvesting, in the three years 1956-58, of Saaz, Hallertau and Northern Brewer hops grown on a farm near Poperinghe in Belgium. Judged by alpha acids content, none of the varieties was ripe when picking commenced. Furthermore, although Northern Brewer was judged by the grower

to be a later variety than Saaz or Hallertau, analysis showed the reverse to be true.

The rather startling suggestion is made that growers should install their own analytical equipment on the farm and in this way determine when their hops should be picked.

S. C. FANG and D. E. BULLIS. "Study of biogenesis of humulone and lupulone in hops during ripening using isotopic carbon." *Wallerstein Lab. Commun.*, 1958, **21**, 107.

The time of formation of the different constituents of the hop resins, is a somewhat controversial subject. This recent work with Fuggle hops in the U.S.A., using radioactive carbon, supports the findings of Howard and Tatchell (*J. Inst. Brew.*, 1956, **62**, 251; 1957, **63**, 333) with Fuggle and Wye variety hops in England, that the alpha and beta acids appear simultaneously.

M. KOTRLA-HAPALOVA. "Formation of bitter acids during the ripening and ageing of hops." *Brauwelt*, 1957, **97**, 745 and 856 (from *J. Inst. Brew.*, 1957, **63**, 442).

With Czech (Saaz) hops it is reported that the development of beta acids is more than half completed before the alpha acids begin to form. It is claimed that the proportion of alpha and beta acids found in Czech hops is characteristic of fine quality hops.

MINERAL NUTRITION

F. ZATTLER. "On the importance of the micro-nutrient boron for the hop plant. With studies on injuries caused by excessive boron manuring." *Hopfen Rundschau*, 1958, **9**, 344 and 362.

R. MAROCKE. "Studies on boron toxicity in hops." *Ann. agron.*, 1958, **9**, 406.

There is, as yet, no evidence that deficiencies of trace elements are of any significance in hop growing in England, though one or two isolated cases of boron deficiency have been observed in Hereford. Boron deficiency has also been reported in New Zealand and in Germany, but the above papers, from Germany and France respectively, draw attention to the risk of inducing boron toxicity through excessive applications of boron.

V. M. BONDARENKO and V. M. PARŠIKOV. "The effect of manganese on the physiology and productivity of hops." *Dopovidi AN U.R.S.R.*, 1957, No. 2, 196 (from *Horticultural Abstracts*, **29**, 2684).

V. P. PROČAJEV. "The effect of certain chemicals on the preservation of the colour of hop cones." *Chmelářství*, 1958, **31**, 148 (from *Horticultural Abstracts*, **29**, 2689).

In the above papers research workers in Russia claim that applications of manganese can improve the growth and development of hops. Furthermore spraying with potassium permanganate is said to have preserved the yellow-green colour of hops when picking was delayed.

DISEASE CONTROL

Downy Mildew

C. E. HORNER and C. R. MAIER. "Antibiotics eliminate systemic downy mildew from hops." *Phytopathology*, 1957, **47**, 525.

C. R. MAIER and C. E. HORNER. "Absorption and translocation of streptomycin by hops." *Ibid*, 1957, **47**, 528.

C. R. MAIER. "Streptomycin absorption, translocation and retention in hops." *Ibid*, 1960, **50**, 351.

J. M. OGAWA, A. H. MCCAIN and D. H. HALL. "Streptomycin absorption in diseased and healthy hop tissues, and its effect on the hop downy mildew organism and mildew development." *Ibid*, 1960, **50**, 278.

Plant pathologists would welcome the development of a satisfactory systemic fungicide, but killing the fungus in the plant involves great risks of killing the plant itself. Nevertheless, recent work at the Oregon State College in the U.S.A. reported in the first three papers above, claims that the antibiotics streptomycin and griseofulvin have been used successfully for the control of hop downy mildew. Work in California, however, reported in the paper by Ogawa *et al.*, does not support the Oregon findings. It must also be recorded that at Wye trials with streptomycin have not, so far, proved successful (see this Report for 1958, p. 29).

F. ZATTLER. "Report of the hop experiment station at Hüll for 1958." *Dtsch. Brauw.*, 1959, **68** (10 Suppl.).

Breeding for field resistance to downy mildew has been carried out at the German hop research station at Hüll for over thirty years, and is well in advance of similar work at Wye which, in fact, is based on material obtained from Hüll in 1954.

This report records the results of variety trials with four downy mildew resistant seedlings which are now in farm trials for assessment by an official Valuation Commission, representative of

brewers, merchants and growers. It would be a great advantage if some similar system could be adopted in England.

Verticillium Wilt

The above report from Hüll also records that one of the most important problems under investigation is the incidence and spread of *Verticillium* wilt in Germany. In collaboration with English workers efforts are being made to assess the status of the German strain in relation to the Fluctuating and Progressive types of wilt known in England. Under English conditions, with Fuggle hops, the German strain behaves like Fluctuating Wilt, but under field conditions in Germany with Hallertau hops the disease is much more severe.

PLANT MORPHOLOGY AND PHYSIOLOGY

Fundamental research on the botanical structure of the hop plant has been reported recently from the U.S.A. This covers important work on the classification of hop varieties and on the morphology of hop roots, as reported in the following papers.

E. L. DAVIS. "Morphological complexes in hops (*Humulus lupulus* L.) with special reference to the American race." *Ann. Mo. bot. Gdn.*, 1957, **44**, 271.

This paper describes a method of measuring variation between hop varieties, depending on certain botanical characteristics of the leaf and cone. Using this method cultivated hops were found to fall into three morphological complexes, comprising English varieties, German-Czechoslovakian varieties and the American variety Late Clusters. In the south-west of the U.S.A. American wild hops are known to be indigenous and are very variable botanically. It is not possible, as yet, to classify them as morphologically distinct from European hops.

R. H. MILLER. "Morphology of *Humulus lupulus*. I. Developmental anatomy of the primary root", and "II. Secondary growth in the root and seedling vascularization." *Amer. J. Bot.*, 1958, **45**, 418 and 1959, **46**, 269.

HOP CULTURE

F. HOED, J. HOED and A. SPELEERS. "Study of the forcing of hops at the Institut National Belge du Houblon." *Pet. J. Brasseur*, 1960, **68**, 20.

A comparison was made between the growth of a hop plant in

a glasshouse and hops grown in the open, in order to study the effect of temperature on yield and resin content.

In the first year, the plant under glass produced similar growth to plants in the open, but gave a lower yield. Humulone content, however, was higher under glass.

In the second year the glasshouse plant gave three crops, but the first two were insignificant in weight. However, the *total* yield of the glasshouse plant was well above that of plants in the open, as was the humulone content.

It is considered that the high and uniform temperature obtained in a glasshouse can have beneficial effects on the yield and resin content of hops, but that the expensive equipment required makes glasshouse culture commercially uneconomic.

HOP DRYING

S. M. HENDERSON. "Some hop drying studies." *Bull. Calif. agric. Exp. Stat.*, **762**, 1958.

This bulletin summarizes the results of hop drying studies carried out over four seasons, in the U.S.A. The investigations covered a wide field and included the effect of drying temperature on quality, and the use of high air speeds. Hops dried at 110°-115° F. were judged superior to samples dried at higher temperatures. An air speed of 60 ft. per minute was considered to be the maximum for a 3 ft. bed of hops; higher air speeds tended to lift the hops.



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